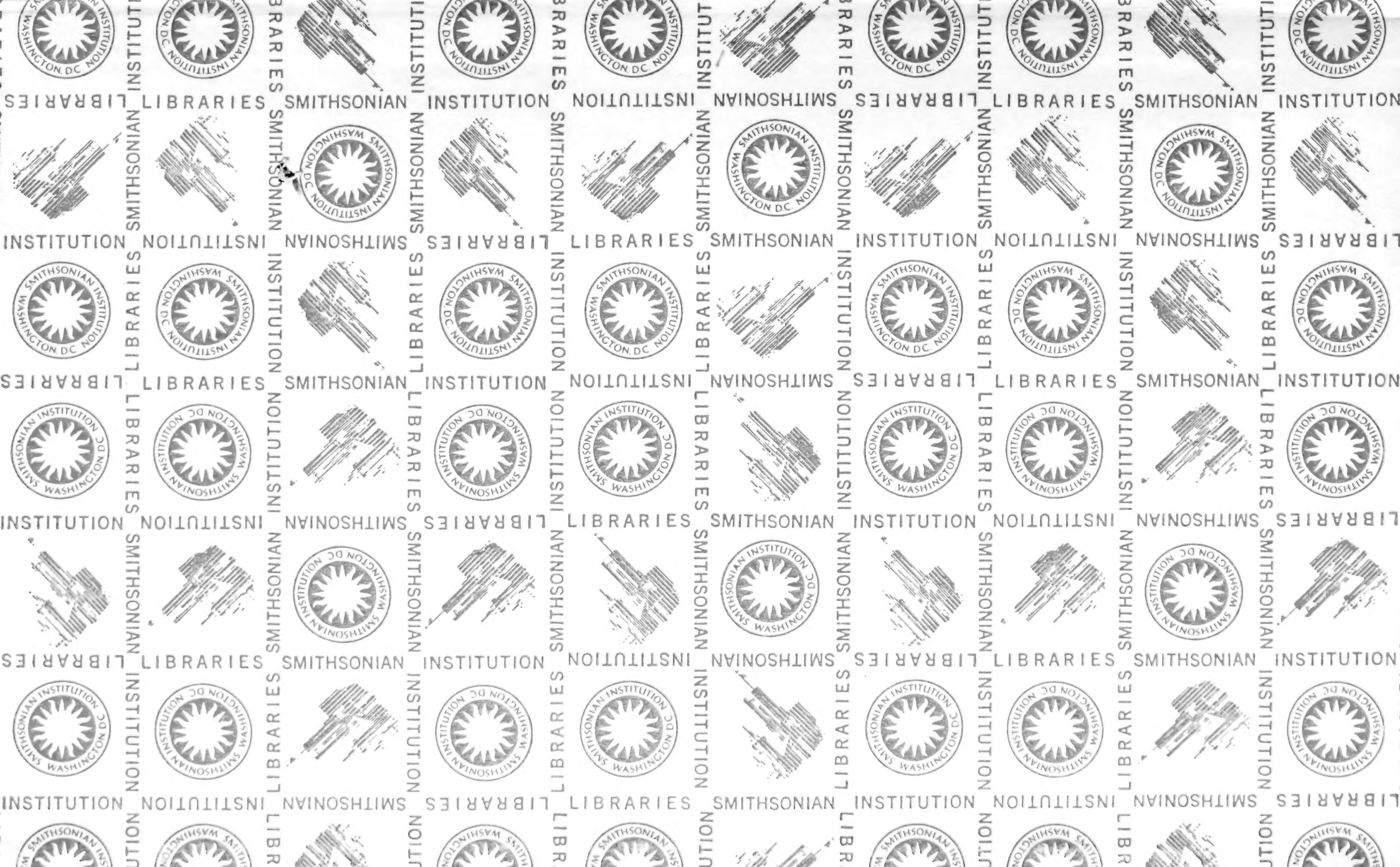
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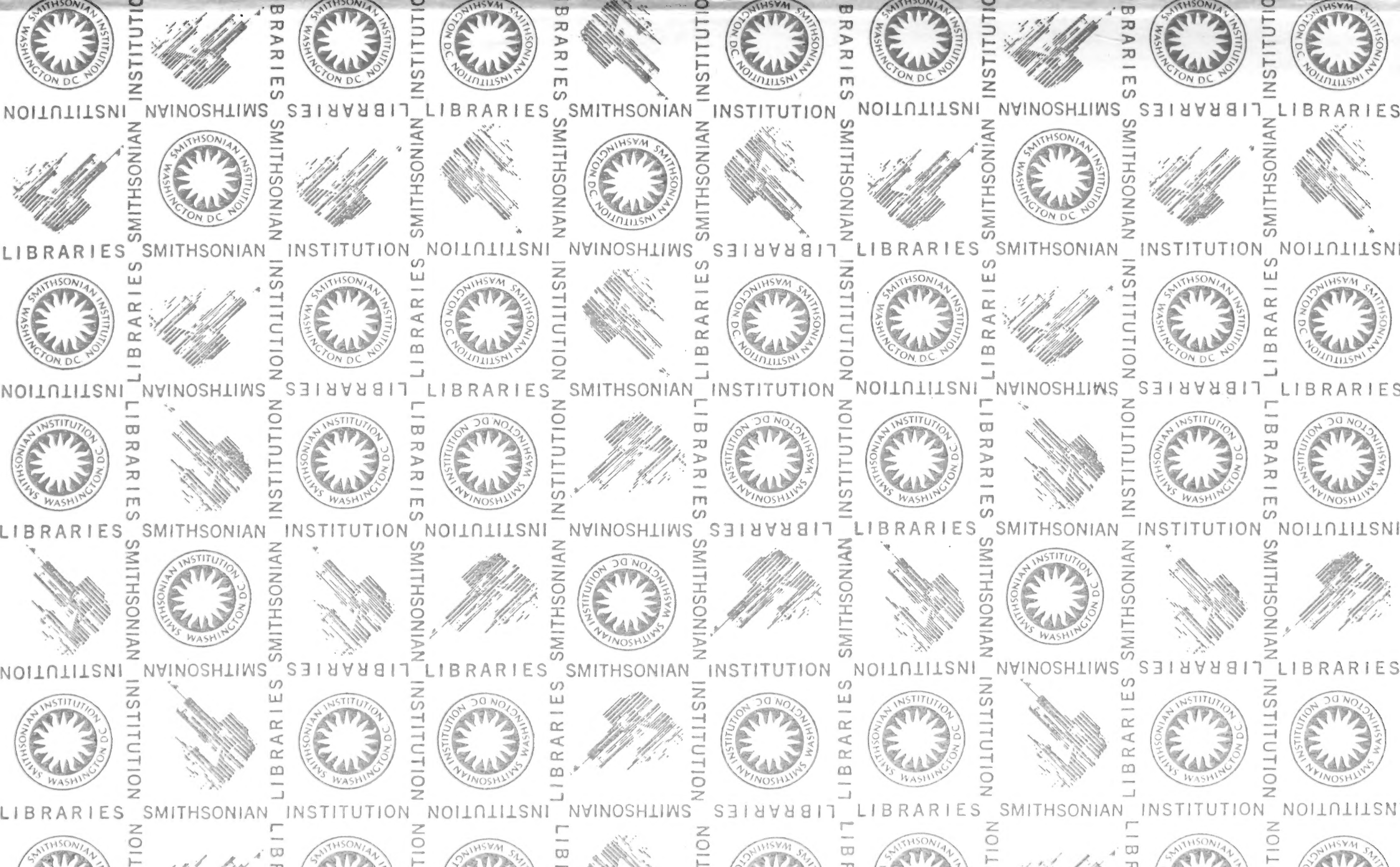
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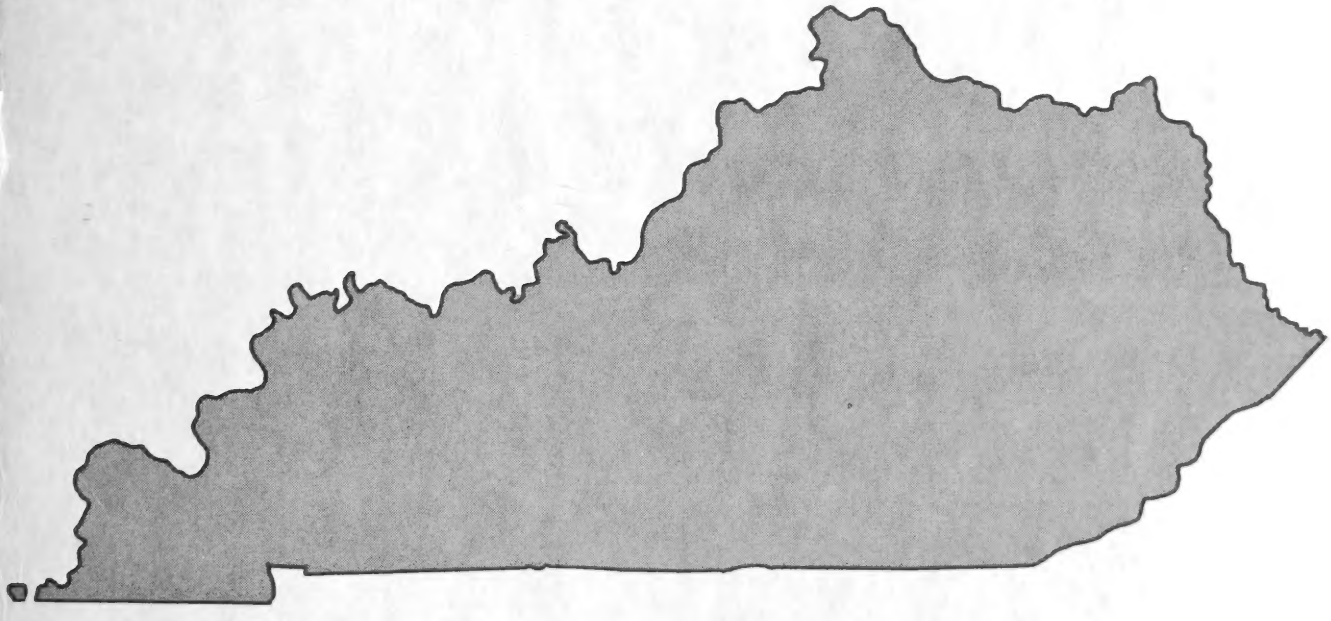

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Thomas Hunt Morgan

HERBERT PARKES RILEY

Thomas Hunt Morgan School of Biological Sciences
University of Kentucky, Lexington, Kentucky 40506

The Hunt-Morgan House is associated with two nationally or internationally famous Americans. It was the home of General John Hunt Morgan, a Confederate general and cavalry leader whose exploits as head of "Morgan's Men" placed him high on the Union's "most wanted" list. Probably better known, and certainly better known outside the United States is his nephew, Dr. Thomas Hunt Morgan, a professor of biological sciences whose pioneer studies in the field of classical genetics opened up a new and exciting area of biological research, and laid the foundations for the vast amount of work in biochemical and molecular genetics that has developed since the end of World War II.

Dr. Morgan's father was Captain Charlton Hunt Morgan who rode with the general's band during the War Between the States, and his mother was Ellen Key Howard whose grandfather, Francis Scott Key, was the author of "The Star-Spangled Banner." Dr. Morgan was descended from the early Anglo-Saxon stock who founded and built up the country during colonial days, and in height, appearance, and manners he was very much a southern gentleman. In his ancestral lines were several old, aristocratic families of Pennsylvania and Maryland. He was born on 25 September 1866 in the Hunt-Morgan House, which has sometimes been called Hopemont. Apparently, he was named for his uncle, Lieutenant Thomas Hunt Morgan, a member of Morgan's Raiders, who had been killed in a skirmish at Lebanon, Kentucky, in 1863.

In 1880, Dr. Morgan entered the Agricultural and Mechanical College of Kentucky (now the University of Kentucky) as a student in the preparatory department. Two years later he became an undergraduate and received his Bachelor of Science degree, with highest class honors, in 1886.

Dr. Morgan had shown an early interest in natural history, and was an avid collector of birds, birds' eggs, and fossils before he was 10 years old, so it was only natural that as an undergraduate his chief interest would be in that subject. He was fortunate to study under A. R. Crandall, a professor in the Department of Natural History, from 1878 to 1888. Apparently, Professor Crandall maintained high academic standards, for Dr. Morgan had to take a year of organic and inorganic chemistry as a prerequisite to a major in the department. He later wrote of Professor Crandall (letter to President Frank L. McVey at the time of a University of Kentucky Convocation on 25 September 1936 in honor of Dr. Morgan) "I have never met with a finer character or better teacher. I realize the very great debt I owe to these earlier experiences."

During his student days, the college, including the preparatory school, had an enrollment of a little more than 300 students

and about 20 faculty members. Lexington was a very small town in a distinctly rural environment and was not then ringed, as it is today, by residential suburbs and shopping centers. It was a paradise for the student of natural history. Dr. Morgan was an excellent student and was valedictorian of his class at the graduation exercises, but he had a lighter side as well, and accumulated a number of demerits for tardiness at chapel and for disorder in class and in the halls. His only low mark was in French, and for a most unusual reason. Professor François M. Helveti, the instructor in French, had been a soldier in the Union army during the War Between the States and had been captured by General Morgan's men and forced to ride backwards on a mule from Cincinnati to Lexington. Such an indignity provoked a hatred for the Morgan family that prevented him from being objective when it came to Dr. Morgan's grade in French.

In the autumn of 1886, Dr. Morgan entered The Johns Hopkins University for graduate work in biology. This was a fortunate choice, as The Hopkins was, under the leadership of Daniel Coit Gilman, one of the superior graduate schools in the United States and one of the few institutions in the country that offered the degree of Doctor of Philosophy. It was a fortunate choice, too, because it had an excellent faculty in biology which included Professor William Keith Brooks and several others of note, and a group of fellow students, such as H. V. Wilson, E. G. Conklin, S. Watase, and R. G. Harrison, who became leaders in the biological sciences at the turn of the century. Professor E. B. Wilson, later a colleague of Dr. Morgan at Columbia University, had preceded him as a graduate student at The Hopkins by just a few years.

In 1888, the State College of Kentucky awarded Dr. Morgan the degree of Master of Science on the basis of work done there during his senior year plus work done for two years in absentia while he was a graduate student at The Johns Hopkins University. On 5 June 1889, the Board of Trustees of Kentucky elected him to a professorship, and the Annual Register of the State College of Kentucky for 1888–1889, with the announcements for 1889–1890, listed Thomas Hunt Morgan as Professor of Natural History. However, on 13 June 1889, Dr. Morgan wrote to President James K. Patterson declining the appointment as he had just accepted an appointment as Fellow in Morphology at The Hopkins and hoped to apply for his degree of Doctor of Philosophy at the end of the year. He wrote that the fellowship generally led to the Bruce Fellowship for one or more years and that by accepting it he could devote himself for one or two years entirely to research in zoology. He received his doctoral degree in 1890 and remained for one postdoctoral year as a Bruce Fellow. At that time he had no thought of being a geneticist. His field was experimental embryology, and his doctoral dissertation was entitled "Embryology and Phylogeny of the Pycnogonids (sea spiders)."

Bryn Mawr College in Philadelphia offered him a professorship in 1891 and he accepted it. He taught there for 13 years and, as in his graduate studies at The Johns Hopkins University, was preceded there by Professor E. B. Wilson, who left the year Dr. Morgan joined the faculty. His Bryn Mawr experience was a very significant one, as during his later years he became engaged to Miss Lilian Vaughan Sampson, a graduate student in biology and an excellent violinist. She was a first-class biologist in her own right and published a number of articles in technical scientific journals after she was married. Their marriage took place in June 1904 and they became the parents of four children.

In 1904, Dr. Morgan was called to the new Chair of Experimental Zoology at Columbia University in the City of New York. In a sense, this appointment was the turning point of his professional career because it gave him facilities that he could never have had at Bryn Mawr. His teaching load was lighter, the library was much better, and he had many first-class graduate

students. In addition, there was a much larger group of stimulating biologists in the faculty, including Professor E. B. Wilson, whose field was closely allied to Morgan's. The inclusion of both men in the same department was mutually very beneficial.

One of the great benefits that Dr. Morgan derived from his Columbia professorship was access to three unusually brilliant graduate students who were there at the same time, and who, along with their professor, formed a harmonious team which, in a sense, was the forerunner of the numerous scientific teams of the present day. They were H. J. Muller, C. B. Bridges, and A. H. Sturtevant. In recognition of their assistance, Dr. Morgan shared his Nobel Prize money with the two who were still with him in 1933 when he received it.

In 1920, the California Institute of Technology was formed from a smaller and less renowned technical school near Los Angeles. In 1928, it expanded to include biology, and Thomas Hunt Morgan was appointed Chairman of the Division of Biology, Director of the Wm. G. Kerckhoff Laboratories, and a member of the Executive Council of the Institute. There, he had an even greater opportunity to develop the science of genetics than he had as a professor at Columbia University. Naturally, the Division of Biology tended to emphasize genetics as he added his former students Dr. Bridges and Dr. Sturtevant to the staff as well as several other geneticists from other institutions. He remained as Chairman of the Division and Director of the Kerckhoff Laboratories until 1941, when he retired at almost 75 years of age. "Retirement," however, is a relative word, and Dr. Morgan continued his biological research after he gave up his more formal duties, and until a short time before his death, which occurred 4 December 1945, at the age of 79 years.

Dr. Morgan was one of a group of biologists responsible for establishing the well-known Marine Biological Laboratory at Woods Hole, Massachusetts. Especially during the early part of this century it was a tremendously active research laboratory for aquatic biology, and many famous biologists of that period spent their summers there. Dr. Morgan built a home at Woods Hole in 1907 which he maintained until 1944, and he spent every summer there during that period with two exceptions. The house had a double living room 80 feet long and 25 feet wide, and a large dining room and kitchen. On the second floor were six bedrooms, two sleeping porches, and one household bathroom. The third floor had four huge unfinished rooms for the maids. No architect was used, and the total cost for lumber and labor was $3,000. While there, he entertained many of the famous biologists of Europe. In addition to his periodic visits to the Marine Biological Laboratory, he made other trips to collect material and to consult with investigators in other laboratories. They included the West Indian island of Jamaica, the Stazione Zoologica in Naples, and the Universities of Berlin, Zurich, Helgoland, and other places.

During his academic career, Dr. Morgan published 14 books with a total of almost 5,000 pages. His first, published in 1897, was on the development of the frog's egg, and his last, in 1934, was on embryology and genetics. Perhaps the one that had the greatest impact on biology was "The Mechanism of Mendelian Heredity" authored by T. H. Morgan, A. H. Sturtevant, H. J. Muller, and C. B. Bridges. It was originally published in 1915 and was revised in 1923. It brought together and summarized the evidence which that team had been accumulating in support of Mendelism and the chromosome theory of heredity, and from then on the chromosome theory was well accepted and no longer under suspicion except by a few diehard biologists. In addition to the books, Dr. Morgan published more than 300 articles in technical biological journals.

Experimental embryology was a fashionable biological subject in the 1880's and 1890's and Dr. Morgan was one of its

leaders. According to Muller (1946), he was "an outstanding member of what may be called the heroic generation of American biologists—those whose work raised American biology to a position second to none among the countries of the world." During that period, biology was in a very unsettled state. In many ways it had not attained the status of a science, and it tended to be confounded and obfuscated by philosophical or pseudophilosophical speculations that all too frequently were substituted for experimentation and the objective procurement of facts.

One of the big controversial problems was the fundamental one of the essence and substance of life. The two principal theses were *mechanism* and *vitalism* and they were mutually antagonistic. The former hypothesized that living things were fundamentally the same as nonliving, that that they were composed of the same kinds of molecules, and that they operated according to the same laws that controlled the reactions of inanimate objects. The vitalists, on the other hand, assumed that life is partly self-determining, that it cannot be explained by the laws of chemistry and physics alone, and that its functions and behavior are not purely mechanistically determined. The vitalists refused to explain life in concrete terms with the result that subjects such as embryology, heredity, regeneration, organization, and evolution frequently seemed to be enshrouded in an air of mystery.

Dr. Morgan was an experimentalist who believed in exact observation. He was one of a group of biologists of that period who detested and scorned speculation and all generalization based on inadequate information, and who felt that the important need was for more data, more information, before conclusions could be drawn or generalizations made. This attitude was frequently called "mechanistic," especially by those not in rapport with it. Morgan's philosophy on that subject can be readily understood from a biographical note he published in Science (Morgan 1912) about Miss N. M. Stevens, a former student of his at Bryn Mawr College; she was a first-class cytologist who made some significant observations on chromosomes and the inheritance of sex in animals. He wrote "She was a trained expert in the modern sense—in the sense in which biology has ceased to be a playground for the amateur and a plaything for the mystic."

Early work of Dr. Morgan involved, among other problems, the importance of the structure of the egg to the development of the individual. It was a problem that interested him all his life. In the preface to his "Experimental Embryology" (Morgan 1927), he wrote "A transparent egg as it develops is one of the most fascinating objects in the world of living things. The continuous change in form that takes place from hour to hour puzzles us by its very simplicity. The geometric patterns that present themselves at every turn invite mathematical analyses. The constancy and orderliness of the whole series of events, repeating themselves a thousandfold in every batch of eggs, assures us of a causal sequence conspiring to create an object whose parts are adjusted to make a machine of extraordinary complexity."

Some of the early embryological studies were fascinating because of the meticulousness of the observations and the ingeniousness of the methods used to devise critical experiments. During the early stages of the development of the embryo, the first cell to be formed, the zygote, divides into 2, those 2 divide into 4, then into 8, 16, 32, and finally into a mature individual that consists of hundreds of thousands or millions of cells. A study of this development requires great patience and keen observation, for growth and differentiation are very precise and follow a rigid pattern, any deviation from which would result in an abnormal individual. The pattern, however, may differ with different species or kinds of animals.

Those most frequently studied are lower marine invertebrates because their eggs are readily obtainable in tremendous quantities and are not too difficult to study

under the microscope. Various zoologists in Europe and the United States studied different organisms; Morgan's main observations were on the frog, and culminated in 1897 in a small book on "The Development of the Frog's Egg." He traced the normal development of the egg, cell by cell, from its beginning until late in the development of the tadpole.

During that period of biological research, many zoologists were studying the egg under abnormal conditions to determine whether they could learn more about normal development by studying the abnormal rather than the normal. Various means were used to produce unusual conditions. Eggs were kept compressed in certain planes, cells or parts of cells were destroyed with hot needles, developing embryos were raised in sea water lacking or containing too much of certain salts, eggs were subjected to violent centrifugal force before or during development, nuclei were removed from cells, pieces of the egg were sliced off, and both nucleate and enucleate egg fragments were fertilized and allowed to develop as they would. Morgan tried all these methods on frogs and other animals, such as sea urchins and marine polychaete worms, and from these studies many valuable principles of development were discovered and understood. Morgan's interests in the field of experimental embryology were extensive throughout his life, and the problems he attacked were many and varied.

Early in the twentieth century, Morgan turned from his study of experimental embryology to the newly emerging field of genetics or the science of heredity. In 1865, Gregor Mendel, living in a monastery in Brunn, a town then in Austria, now in Czechoslovakia, presented a talk before the natural history society of that town in which he explained in considerable detail the results of a series of experiments he had conducted on the breeding of peas; he also suggested a theoretical explanation of his results. His talk was published the following year in the transactions of that society, but did not attract the attention of the biological world.

At the end of the century, similar experiments were being carried on independently by Hugo de Vries in Holland, Carl Correns in Germany, and Eric von Tschermak in Austria. They all obtained the same results and came to the same conclusions, and in 1900 each published his own data and conclusions. In the meantime, they came across Mendel's original work and realized that their conclusions had been anticipated by 35 years.

When the rediscovery of the principles that Mendel had originally discovered became known to the biological world, there was a mixed reaction. Some biologists saw in them the answer to all problems of heredity and evolution, but others were very skeptical or even hostile to their acceptance. Some people thought they were not true and some thought that even if they were true they were not universal, but applied only to the garden pea or to just a few organisms.

It is very interesting to note that Dr. Morgan was one of a group of biologists who were critical of parts of Mendel's scheme. Morgan started his work in genetics in 1908 (Stubbe 1933), and in 1909 he gave a talk at a meeting of the American Breeder's Association in Columbia, Missouri, in which he expressed a doubt that the hereditary factors, which we now know as "genes" existed at all. He proposed instead, that the condition of two contrasting characters, such as round or wrinkled peas, might be the result of alternative states of stability or conditions which determine the traits of which an individual is composed, rather than the result of the clean and absolute segregation of material bodies such as genes.

The principal event that changed Morgan's attitude towards genetics was the discovery of a white-eyed fly. Within three years of the rediscovery of Mendel's laws, a graduate student by the name of W. S. Sutton, who was studying at Columbia University, observed the striking parallelism

in the behavior of chromosomes during cell division and the formation of germ cells and the hereditary factors that Mendel had hypothesized. He emphasized that it could not be purely coincidental, and maintained that these hereditary factors must be located in the chromosomes, thus laying the foundations for the chromosome theory of heredity. Not all biologists accepted such a revolutionary doctrine.

At about the same time, several zoologists were concerned with the problem of the determination of sex. It had been shown by some that females in many animals apparently had two members of a certain chromosome, now designated the "X chromosome", whereas the males had only one, and it was suggested that this difference determined whether the animal was a male or a female. However, other zoologists found that in other animals the reverse condition seemed to be true, the male having two such chromosomes and the female only one. Confusion reigned, and the problem of sex determination seemed to be a very baffling one.

Most of Dr. Morgan's work in genetics was done with a tiny two-winged fly called *Drosophila melanogaster*; its popular names are pomace fly, fruit fly, or vinegar fly. If a person should put some bananas outdoors in the spring or summer, he would probably soon find some of these flies flitting around them. If he collected and examined them, he would find that they would invariably have eyes of a certain shade of red. Such flies, collected under natural or "wild" conditions are said to have "wild-type" characteristics or traits. This peculiar shade of red is then called the wild-type eye color. Morgan had had a number of such wild-type flies in his laboratory for many generations. It was, therefore, a great and pleasant shock when one morning he found a white-eyed male in a laboratory stock bottle. Of course, there was only one thing to do with such a fly—mate it immediately to a wild-type-eyed virgin female to see what would happen. Probably to his surprise, Dr. Morgan found that wild-type and white eyes behaved exactly as they should if they were determined by a pair of those hereditary factors or genes at the basis of the Mendelian laws of heredity. Furthermore, not only did they behave according to Mendel's laws, but they also followed a pattern that would indicate that they were located on the X chromosome, or were "sex-linked," to use the technical expression. Their pattern of transmission from one generation to another was the same as the pattern that Miss Stevens had observed for the X chromosome of *Drosophila*.

It was then finally recognized that birds and butterflies show one type of sex inheritance and sex-linkage, and the Diptera, mammals, and other animals show another, and that these two types are fundamentally the same except that in one the female has the odd chromosome, and in the other, the male has. It was also seen that Morgan's example of white eye inheritance in the fruit fly follows the same pattern of heredity as do certain sex-linked traits in human beings, such as hemophilia and a certain kind of color blindness.

Very soon after the discovery of the white-eyed male, a male appeared with short wings. This trait happened, by chance, also to be sex-linked and thus to follow the same pattern of transmission that was followed by the white-eyed character. Experiments soon showed that these two genes, white eyes and short wings, were linked together, which is just what they should have been if they were on the same chromosome. Dr. Morgan then crossed these two types together and found that although they were linked and therefore tended to be inherited together, they would sometimes show recombinations. Such recombinations of otherwise linked genes had been found in other organisms by other biologists but had never been satisfactorily explained.

Morgan reasoned that the chromosomes must break and interchange similar pieces at some time early in the divisions that produce the germ cells in animals. This

theory of crossing over was supported by observations that had been made by F. A. Janssens, a Belgian cytologist, in 1909. He had shown that in a very early stage of these divisions, cross-shaped chromosome configurations could be seen under the microscope that were exactly what one would expect to find if the chromosome broke and crossed over as Morgan hypothesized (Morgan 1911a, 1911b). Recent observations have substantiated these ideas and have shown that crossing over involves exchanges of pieces of half chromosomes, as Janssens had originally suggested, and not whole ones, a very minor point.

The crucial point is that these observations caused Dr. Morgan to reverse some of his former ideas about Mendel's laws. Instead of being skeptical of them, he now accepted them wholeheartedly and spent most of the rest of his life confirming and expanding them. Only a great man would have done so, as many people, confronted with evidence opposed to their hypotheses would tend to find ways to look for confirmatory evidence, rather than give up their cherished hypotheses.

After demonstrating sex-linkage and showing that two sex-linked genes are linked to one another, Morgan extended his genetic studies. From 1909 to 1912, he and his group found many new mutations in *Drosophila.* After 1910, they attacked the problem of crossing over with great vigor, and published the first edition of their masterful "The Mechanism of Mendelian Heredity" in 1915. Morgan's greatest contribution was the study of linkage and crossing over. He demonstrated beyond doubt that genes located on the same chromosome sometimes separate from one another and that they do so more frequently if they are farther apart on the chromosome. With this demonstration, linkage maps, based on breeding data, could be constructed and the whole chromosome theory was substantiated.

While Dr. Morgan's earlier work was in the field of experimental embryology, and while the work for which he is best known was the genetic study of *Drosophila,* it should also be mentioned that he carried on extensive research on regeneration, and on the life cycle and cytology of the phylloxerans, a group of plant lice. These studies were important in influencing the thinking of the time.

Dr. Morgan's list of honorary degrees is extensive. He received the Doctor of Laws degree from The Johns Hopkins University (1915), the University of Kentucky (1916), McGill University (1921), the University of Edinburgh (1922), and the University of California (1930). The University of Michigan awarded him the degree of Doctor of Science in 1924, and the University of Heidelberg (Germany) gave him the degree of Doctor of Philosophy in 1931. In 1933, he received the degree of Doctor of Medicine from the University of Zurich (Switzerland), and two years later the University of Paris awarded him the degree of Docteur Honoris Causa.

He was President of the National Academy of Sciences from 1927 to 1931, of the American Association for the Advancement of Science in 1930, and of the Sixth International Congress of Genetics in 1932. He was a member of the American Philosophical Society, the Academy of Natural Sciences of Philadelphia, the American Society of Naturalists, and other American scientific organizations. He was an honorary member of many European societies including the Royal Society of London, the Paris Academy of Science, Belgian Society of Zoology, Royal Society of Science of Uppsala, Vienna Academy of Science, and other scientific societies in France, Norway, Denmark, Ireland, Finland, Brussels, Moscow, St. Petersburg, and Munich. He was one of the members of the editorial board of GENETICS from the time it was founded in 1916 until his death.

Of his many important scientific contributions, the greatest was the work in genetics that clinched the acceptance of Mendel's laws, established the chromosome theory, and developed the concept of the linkage and crossing over of genes on a

chromosome. It was for this work that he became the first man without a medical degree to be awarded the Nobel Prize in Physiology and Medicine.

LITERATURE CITED

MORGAN, T. H. 1911a. The application of the conception of pure lines to sex-limited inheritance and to sexual dimorphism. Amer. Nat. 45:65–78.

———. 1911b. An attempt to analyze the constitution of the chromosomes on the basis of sex-linked inheritance in *Drosophila*. J. Exp. Zool. 11:365–411.

———. 1912. The scientific work of Miss N. M. Stevens. Science 36:468–470.

———. 1927. Experimental Embryology. Columbia Univ. Press, New York, N.Y. 766 pp.

MULLER, H. J. 1946. Thomas Hunt Morgan 1866–1945. Science 103:550–551.

Stubbe, H. 1933. Thomas Hunt Morgan—der Nobelpreisträger für Medizen. Der Züchter 5:257–260.

A "Container Effect" on ^{14}C Primary Production Measurements

BRUCE C. PARKER AND GENE L. SAMSEL[1]
Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

ABSTRACT

Comparative data on in vitro ^{14}C rates of primary production in 6 different kinds of containers yielded differences of more than an order of magnitude quite consistently. Experiments involving light penetration through and into the various containers, chlorophyll analyses, surface area/volume differences, etc. suggested that at suboptimal light intensities an inexpensive, screw cap, 250-ml (8-oz) pharmaceutical bottle produces results more closely approaching primary production rates in nature.

INTRODUCTION

Since the introduction of the light and dark bottle method for estimating primary production, numerous investigators have pointed out inherent problems in equating the observed in situ primary production with that of the natural environment. Such problems include: (1) Surface/volume ratio effects of the containers (Antia et al. 1963); (2) Injury to cells during filtration, inducing loss of intracellular ^{14}C organic matter (Arthur and Rigler 1967); (3) Spatial heterogeneity of the plankton sampled (Cassie 1962, Verduin 1964); (4) Precipitation of $^{14}CO_3$ as Fe_3CO_3 (Goldman and Mason 1962); and (5) Orientation of containers with respect to the light source (Ohle 1958, Elster and Motsch 1966). Still other problems are changes in pH, light, temperature, circulation, nutrients, biotoxins, and microbial communities induced by the containers, some of which were forewarned in studies reviewed by Lund and Talling (1957) shortly after Steemann Nielsen's (1952) ^{14}C method came into widespread use.

Vollenweider (1969) provided an up-to-date list of many problems associated with the measurement of primary production. One such problem, which especially concerns our research, is that soft glass absorbs more photosynthetically influential light (especially ultraviolet) than does quartz; since ultraviolet often is detrimental to the photosynthetic system, carbon assimilation rates in Pyrex or quartz bottles can be 50 percent less than in soft glass ones. Also, in Vollenweider (1969), Talling and Fogg (p. 74) noted "Some loss of light by absorption and reflection, will occur at or in the transparent walls of the bottles or enclosures. Such loss is only likely to be considerable in the far ultraviolet region of the spectrum, where normal glass absorbs strongly. . . ."

While surveying the ecology of several freshwater ponds and meltwater pools on the Antarctic Peninsula, we first became aware of the striking differences in measurable primary production induced by different containers. Faced with a shortage of typical 300-ml glass-stoppered (BOD) bottles used extensively by limnologists, we resorted to 8-oz (250-ml) screw cap pharmaceutical type bottles also made of soft glass. Consistently, these 250-ml bottles yielded ^{14}C uptake rates significantly above (i.e., up to 60% higher than) values obtained with the standard 300-ml bottles. Since it is clear from the literature that a great variety of bottles, plastic bags, or special chambers (e.g., domes) have been used for estimating primary production, we began comparisons of several of these containers in an effort to explain their differences.

[1] Present address: Dames and Moore, 1150 West 8th Street, Cincinnati, Ohio 45203

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MATERIALS AND METHODS

Our primary production studies were conducted mainly in the field using several aquatic environments. While the precision of alternative laboratory experiments cannot be discounted, the difficulties in duplicating conditions of natural light scatter, the continuously changing angle of solar radiation source, the complete solar spectrum, natural spatial turbidity differences, natural plankton communities, pH, etc., in our opinion, necessitated the field approach.

The aquatic environments used were: (1) an oligotrophic pond in Antarctica containing *Chlorella* as the only detectable phytoplankter (called C. B. Pond and described by Parker et al. 1972); (2) a farm pond near the Virginia Polytechnic Institute and State University campus, essentially mesotrophic in character with high turbidities, and possessing *Dinobryon* as the chief phytoplankter along with several diatoms; (3) a shallow and eutrophic duck pond on the same campus with *Spirogyra*, *Oedogonium*, *Cladophora*, *Cymbella*, *Melosira*, and *Navicula* among the phytoplankton; and (4) a waste oxidation pond at Sult's Trailer Court, Meramec, Virginia, as pictured and described by Parker et al. (1971), and containing *Chlamydomonas*, *Pandorina*, *Euglena*, and other typical sewage lagoon algae. For primary production, we used the ^{14}C method originally described by Steeman Nielsen (1952) and as modified by Goldman (1963) and Strickland and Parsons (1968). One ml of a solution of $Na_2{}^{14}CO_3$ buffered at pH 9.5 and with an activity of 4 μCi was injected into the containers. All containers, unless otherwise stated, were incubated in their respective aquatic environments at a depth of 20 cm from which the sample had been taken. They were oriented horizontally with convex or rounded sides facing up and with longitudinal axes essentially corresponding to that of the sun's east–west path.

After incubation, 10-ml aliquots were fixed with 40 percent formalin to make a 1:30 dilution for transport to the laboratory. Equal aliquots were filtered through GS 0.22-μ Millipore membranes by procedures outlined by Parker (1967) to avoid excessive loss of intracellular organics. Filters were rinsed routinely with 2 ml of 0.03 N HCl. Periodic checks on the ^{14}C organic matter in filtrates revealed always less than 5 percent of the total ^{14}C organic matter to be extracellular. After storage over desiccant for at least 24 hours, all membranes were counted for 10 min, suspended in 0.4 percent PPO [2,5-Diphenyloxazole] and 0.01 percent POPOP [2,2-p-Phenylenebis (5-phenyl) oxazole] in toluene on a Packard Tricarb Model 3310 Scintillation Counter. Duplicate membranes consistently exhibited less than 5 percent variation.

We used the anthracene method (Dore 1958, Marquis and Yelenosky 1962) as one means of measuring the light penetrating the various containers. Anthracene is a photosensitive compound which has been used as a simple chemical radiometer in terrestrial ecology, and which Parker et al. (1972) applied to aquatic environments. When a tube filled with a benzene solution of anthracene is placed in sunlight, anthracene polymerizes into benzene insoluble dianthracene; the amount of dianthracene produced is approximately proportional to the total visible radiation received during the exposure period. Following exposure, the contents of each tube is filtered to remove the precipitated dianthracene, and the concentration of anthracene remaining in the clear filtrate is determined directly on a colorimeter against a standard curve. We followed essentially the methods described by Marquis and Yelenosky (1962), while using a variety of glass containers and tubes. Our data are expressed as percentage transmittance, because we have found that not all wavelengths of radiation apparently cause anthracene polymerization. Consequently, our anthracene data are only useful

FIG. 1. Six containers used in comparative primary production experiments; top (left to right) and bottom (left to right), they are: 125-ml Pyrex, 150-ml BOD, 300-ml BOD, 2-oz (ca. 70-ml) pharmaceutical, 8-oz (ca. 250-ml) pharmaceutical, and 16-oz (ca. 500 ml) pharmaceutical bottles.

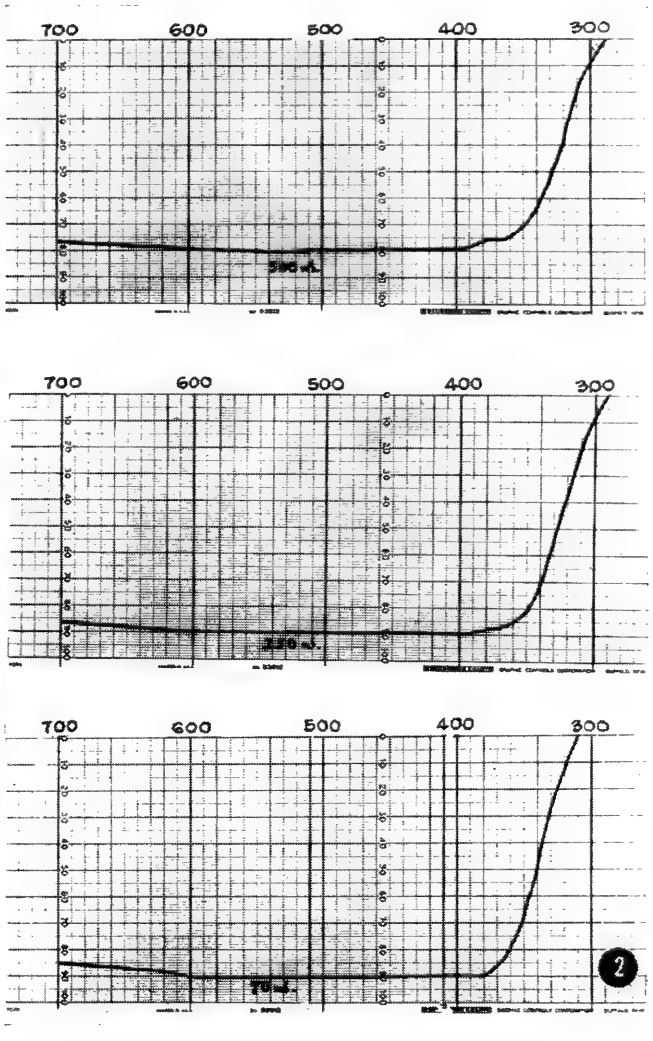

FIG. 2. Normalized curves of percentage transmittance (vertical axis) of light between 700 and 300 mμ (horizontal axis) pieces of glass obtained from each type of container; top to bottom: 300-ml BOD, 250-ml, and 70-ml pharmaceutical bottles.

for comparisons of relative amounts of total radiation penetrating the various containers; we shall discuss this point in detail subsequently. Two additional points should be included as a supplement to the directions by Marquis and Yelenosky (1962): (1) tubes or bottles must be filled with the benzene solution because the reaction does not proceed normally on exposure to air; and (2) if the solution freezes during exposure to light (<0 C) as it did frequently in Antarctica, spurious data result.

Extractable chlorophyll *a* was determined by the method of Strickland and Parsons (1968:189) using the formula 11.64 E_{6630} − 2.16 E_{6450} + 0.10 E_{6300} as recommended by SCOR/UNESCO. Chlorophylls *b* and *c* were not calculated due to their lower reliability with colorimetric analysis. As with the ^{14}C primary productivity procedure, we used GS 0.22-μ Millipore membranes and procedures established by Parker (1967) for minimum cell damage. In addition, we have found it essential that comparative chlorophyll determinations entail (1) filtration of identical volumes at similar pressures and (2) extraction in acetone for identical time lengths (i.e., 20 ± 1 hr at 5–8 C). For highly turbid samples and high phytoplankton densities, we substituted Whatman GF/C fiberglass filters which were removed by centrifugation prior to colorimetric determinations.

The 300-ml soft glass BOD or reagent bottles with ground glass stoppers; the 250-ml (8-oz), 70-ml (2-oz), and 500-ml (16-oz) pharmaceutical screwcap bottles, all of soft glass; the 125-ml spherical Pyrex

TABLE 1.—SELECT DATA ON ^{14}C PRIMARY PRODUCTION (CALCULATED AS MG/M^3/HR PHOTOFIXED), ANTHRACENE POLYMERIZATION (AS % TRANSMISSION OF BENZENE FILTRATE) AND EXTRACTABLE CHLOROPHYLL *a* (AS MG PIGMENT/M^3 EXTRACTED) FOR DIFFERENT CONTAINERS AND DIFFERENT AQUATIC ENVIRONMENTS (– MEANS NO DATA COLLECTED). NONE REFERS TO CHLOROPHYLL ANALYSIS ON WATER SAMPLES NOT INCUBATED IN CONTAINERS; L = LIGHT AND D = DARK CONTAINERS

Experiment No.	Container	Primary Production	Anthracene Polymerization	Chlorophyll *a*
1: 20 January 1970, 25 hr., 10,760–96,840 lux, Antarctic pond.	None	–	–	<10
	250L	3.65, 3.67	70	–
	300L	2.60, leaked	37, 37	–
2: March 1970, 6 hr., 21,520 lux, Farm pond, high turbidity.	250L	0.20	42	Suspended solids interfered with extraction
	125L	0.09	20	
	300L	0.13	20	
	70L	0.10	9	
3: 10 April 1970, 8 hr., 37,660–53,800 lux, Duck pond.	None	–	–	261
	250L	34.2, 30.1	75, 75	574
	250D	–	–	550
	125L	22.2, 19.1	40, 35	316
	125D	–	–	544
	300L	25.6, 22.4	45, 38	502
	300D	–	–	616
	70L	11.6, 10.4	34, 25	506
	70D	–	–	537
	500L	3.6, 3.4	38, 42	486
	500D	–	–	484
4: 12 September 1970, 6 hr., 64,560 lux continuously, Duck pond water in containers on roof of Biology Bldg., VPI & SU	None	–	–	218, 189
	250L	3.6, 3.6	77, 71	52
	250D	1.2	–	134
	125L	12.8, 12.7	70, 69	59
	125D	–	–	197
	300L	3.3, 3.0	49, 47	106
	300D	1.8	–	155
	70L	7.4, 4.3	71, 64	177
	70D	–	–	178
	500L	5.1, 5.0	59, 49	82
	500D	–	–	170
	150L	4.8, 4.6	41, 29	
	150D	–	–	
5A: 3 December 1970, 4 hr., 30,128–36,584 lux, Duck pond.	250L	16.5, 16.4		
	125L	11.0, 11.0		
	300L	9.4, 9.3		
	70L	10.1, 10.0		
	500L	1.3, 1.3		
5B: 3 December 1970, 4 hr., 30,128–36,584 lux, oxidation pond.	None	–		820
	250L	416, 414		960
	250D	–		920
	125L	275, 274		856
	125D	–		840
	300L	245, 243		804
	300D	–		808
	70L	231, 228		900
	70D	–		860
	500L	30, 29		612
	500D	–		876
	150L	40, 38		685
	150D	–		840

bottles with ground glass stoppers; and in a few experiments only, the 150-ml soft glass BOD or reagent bottles with ground glass stoppers used in our comparative studies are shown in Fig. 1. The 300-, 150-, and 125-ml containers are used widely by limnologists and oceanographers. A frequent disadvantage of these glass-stoppered bottles not emphasized in this paper is the tendency for the stoppers to become loose and leak during incubation.

Percentage transmittance measurements at various wavelengths of light between 700 and 300 mμ were conducted on a Beckman DB continuous recording spectrophotometer. For these studies, 3 or more pieces of glass were selected from the main surface of each container after breakage. In the case of the pharmaceutical bottles, 3 pieces were taken from both convex and flat sides. Graphs of percentage transmittance of each piece of glass were obtained against air (no glass) as the spectrophotometer blank. All curves reported subsequently represent normalized curves which have averaged the 3 or more comparable glass pieces. Although detectable variation occurred, the range in variation between curves of separate glass pieces from the main area of the container surfaces (excepting corners) differed by no more than a few percentage points at any one wavelength, and there was considerably less variation over the entire visible spectrum examined.

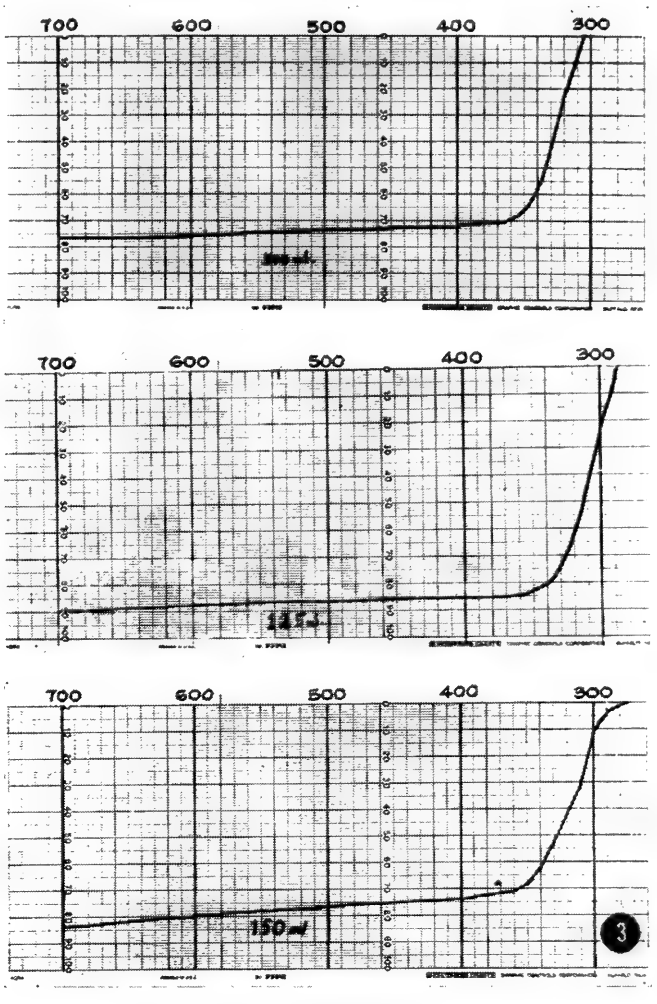

FIG. 3. Normalized curves of percentage transmittance (vertical axis) of light between 700 and 300 mμ (horizontal axis) for 3 or more pieces of glass obtained from each type of container; top to bottom: 500-ml pharmaceutical, 125-ml Pyrex, and 150-ml BOD bottles.

EXPERIMENTAL RESULTS AND DISCUSSION

CO_2 Uptake Rates

Data for 5 experiments involving the different kinds of containers are summarized in Table 1. In the first experiment, the CO_2 uptake rate was about 60 percent higher in the 250-ml bottles than in the 300-ml BOD type bottles. Similarly, anthracene polymerization was significantly greater in the 250-ml bottles, as indicated by the higher percentage transmittance values which, in turn, indicate a greater degree of anthracene conversion to the insoluble dianthracene form caused by a greater amount of light penetrating the 250-ml bottle. Several other experiments comparing photosynthetic CO_2 uptake and anthracene polymerization were performed in Antarctic ponds; all revealed essentially the same types of results.

The data from the second experiment reveal similarly that a higher rate of CO_2 uptake occurred in the 250-ml bottle when compared with that in the 3 other kinds of containers. The greatest polymerization of anthracene also occurred in the 250-ml bottle, suggesting that more light apparently penetrated that type of container.

In the third experiment, the rate of CO_2 uptake in the various containers ranged over nearly an order of magnitude. As

TABLE 2.—LIGHT TRANSMISSION CHARACTERISTICS OF GLASS PIECES AND INTACT CONTAINERS, INCLUDING SURFACE AREA/VOLUME RATIOS

Container	Wave Length Range (mμ)	x̄ % T[1]	x̄ % White Fluorescent Light (via lux meter)	Calculated S/V
250-ml	700–400	89.1		
	400–300	66.2	94.2	0.30
	700–300	83.3		
125-ml	700–400	87.0		
	400–300	74.6	90.4	0.23
	700–300	83.6		
300-ml	700–400	79.0		
	400–300	59.0	86.5	0.24
	700–300	74.0		
70-ml	700–400	88.9		
	400–300	54.6	92.3	0.50
	700–300	88.3		
500-ml	700–400	74.3		
	400–300	52.2	88.5	0.25
	700–300	68.8		
150-ml	700–400	81.2		
	400–300	61.8	88.0	0.25
	700–300	76.4		

[1] x̄ % T = means of >3 planimeter (area) measurements on each original graph with <1% variation of areas of percentage transmissions; expressed as areas of % T/area of 100% T × 100, thus reflecting mean percentage transmission values for the designated wavelength ranges.

before, the 250-ml bottles produced the highest fixation values and the greatest amount of anthracene polymerization. Extractable chlorophyll *a* appeared to increase in all containers, but we discovered subsequently that the value for the fresh collection (261) was not valid for comparison with the values obtained from incubated bottles; a larger volume of the fresh sample had been filtered, and it was extracted 6 hours longer than other samples. Notable among the chlorophyll data of Experiment 3 are the values for the 125-ml light and the 500-ml light and dark bottles; these values may signify some degradation of chlorophyll *a* during incubation.

In the fourth experiment (Table 1), the 250-ml bottles did not produce the highest CO_2 uptake rates. Anthracene polymerization, however, was highest in the 250-ml bottles. Because all bottles were incubated on the roof of the Biology Building, and the light intensity was exceptionally high, we suspect that light and/or temperature might have inhibited the CO_2 fixation rates and caused chlorophyll degradation, which was significant, especially in the light bottles.

In 2 other experiments (5A and 5B), the trends in CO_2 uptake are consistent with those of the first 3 experiments. Also, Experiment 5B was repeated with similar results. No degradation in chlorophyll appears to have occurred in this in situ experiment although the possibility of an increase in chlorophyll *a* exists for some containers, especially 250L, 250D, and 70L. The data in Table 1 represent typical (not biased) data of the type obtained in approximately 10 additional experiments.

Optical Properties of the Containers

Data obtained on the light transmission through the containers and glass pieces obtained from them are shown in Table 2 and Figs. 2 and 3. Note that 94.2 percent of the white fluorescent light (100% = ca. 5,380 lux) penetrated through both walls of the 250-ml bottles, and this amount of light is the greatest recorded for the 6 containers. Also, the spectral data on pieces of glass showed that 89.1 percent of the

spectrum between 700 and 400 mμ was transmitted through the pieces (single wall layer) obtained from the 250-ml bottles, which also constitutes the highest value. As would be expected, more of the near ultraviolet light (300–400 mμ) penetrates the glass of the Pyrex 125-ml flask pieces.

Another parameter affecting the total amount of radiation reaching a container is the surface area exposed to light compared to its volume, the latter of which is an indication of mean depth and relative phytoplankton numbers. Therefore, the data in Table 2 are the calculated surface area/volume ratios, based on the maximal area of cross sections through cylindrical and spherical containers. Note that the 70-ml bottle had the greatest S/A value, while the 250-ml bottle has the second highest S/A value and all others are about equal. These calculations indicate that, on a volume (or per cell) basis, more light will penetrate the 70-ml and 250-ml bottles than other containers.

CONCLUSIONS

Our studies have shown that a wide range in CO_2 uptake rates occurs under a variety of conditions when different containers are employed in light and dark bottle measurements for primary production. Comparisons of data collected with different kinds of containers should be avoided.

The fairly consistent and repeatable pattern of highest CO_2 uptake rates using 250-ml bottles, intermediate rates using 300-, 125-, and 70-ml bottles, and low rates using the 500-ml and 150-ml bottles may be caused by a greater amount of light penetrating the 250-ml bottles. The anthracene data appear to support this conclusion most strongly. The direct measurements of light transmission also show that 250-ml bottles are somewhat more transparent to visible light than any of the other containers including the 125-ml Pyrex flasks. Possibly these small differences in optical properties of the various glass container walls are further increased or decreased by other characteristics of the containers, such as, the surface/volume ratios, differences in reflectance due to curvature of the glass, etc.

At least in some instances, the chlorophyll appeared to increase in the 250-ml bottles and to decrease in the 500-ml and 150-ml bottles. These increases may be the result or the cause of the greater photosynthesis and production during incubation. Also, it is probable that the decreases observed indicate some kind of deleterious effect of enclosure of the phytoplankton within the 500-ml and 150-ml containers. These are matters for further study.

We recognize that this research has left many questions unanswered. However, on the basis of data so far obtained, we feel that the 250-ml pharmaceutical bottle permits an in situ rate of primary production more closely approaching that of the natural aquatic environment than do other containers. Furthermore, the 250-ml bottle with screw cap prevents loss of ^{14}C which can occur in containers with unsecured stoppers, and 250-ml bottles are readily available from drug stores and cost less than 10 percent that of BOD or Pyrex containers. These are the containers we use currently in studies of Kentucky lakes (Samsel et al. 1973).

LITERATURE CITED

ANTIA, N. J., C. D. MCALLISTER, T. R. PARSONS, K. STEVENS, AND J. D. H. STRICKLAND. 1963. Further measurements of primary production using a large-volume plastic sphere. Limnol. Oceanogr. 8:166–183.

ARTHUR, C. R., AND F. H. RIGLER. 1967. A possible source of error in the ^{14}C method of measuring primary productivity. Limnol. Oceanogr. 12:121–124.

CASSIE, R. M. 1962. Microdistribution and other error components of ^{14}C primary production estimates. Limnol. Oceanogr. 7:121–130.

DORE, W. G. 1958. A simple chemical light meter. Ecology 39:151–152.

ELSTER, H. J., AND B. MOTSCH. 1966. Untersuchungen über das Phytoplankton und die organische Urproduktion in einigen Seen des Hochschwartz walds, im Schleinsee und Bodensee. Arch. Hydrobiol. Suppl. 28:291–376.

GOLDMAN, C. R. 1963. The measurement of primary productivity and limiting factors in fresh water with carbon-14. Pp. 103–113. *In*: Proc. Conf. on Primary Productivity Measurement, Marine and Freshwater. Hawaii, 1961. USAEC Doc. TID-7633.

GOLDMAN, C. R., AND D. T. MASON. 1962. Inorganic precipitation of carbon in productivity experiments utilizing carbon-14. Science 136:1049–1050.

LUND, J. W. G., AND J. F. TALLING. 1957. Botanical limnological methods with special reference to the algae. Bot. Rev. 23:489–583.

MARQUIS, D. A., AND G. YELENOSKY. 1962. A chemical light meter for forest research. U.S. For. Serv. Res. Pap. NE No. 165, Upper Darby, Pa., 1–24.

OHLE, W. 1958. Diurnal production and destruction rates of phytoplankton in lakes. Rapp. Cons. Explor. Mer 144:129–131.

PARKER, B. C. 1967. Influence of method for removal of seston on the dissolved organic matter. J. Phycol. 3:166–173.

PARKER, B. C., E. K. OBENG-ASAMOA, AND G. L. SAMSEL, JR. 1971. Effects of detergent protease enzymes on sewage oxidation pond phytoplankton. Bioscience 21:1035–1038, 1042.

PARKER, B. C., G. L. SAMSEL, JR., AND G. W. PRESCOTT. 1972. Freshwater algae of the Antarctic Peninsula. I. Systematics and ecology in the U.S. Palmer Station area. Antarct. Res. Ser. (Amer. Geophys. Union) 20:69–81.

SAMSEL, G. L., JR., J. R. REED, AND R. R. DAUB. 1973. Preliminary investigations of a headwater creek in Eastern Kentucky. Trans. Ky. Acad. Sci. 34:13–21.

STEEMANN NIELSEN, E. 1952. The use of radioactive carbon (^{14}C) for measuring organic production in the sea. J. Con. Internatl. Explor. Mer 18:117–140.

STRICKLAND, J. D. H., AND T. R. PARSONS. 1968. A Practical Handbook of Seawater Analysis. Bull. Fish. Res. Bd. Can. No. 167:1–311.

VERDUIN, J. 1964. Principles of primary productivity: Photosynthesis under completely natural conditions. Pp. 221–238. *In*: Jackson, D. F. (ed.) Algae and Man, Plenum Press, N.Y.

VOLLENWEIDER, R. A. 1969. A manual of methods for measuring primary production in aquatic environments, including a chapter on bacteria. I.B.P. Handbook No. 12. Blackwell Scientific Publications, Oxford, England, 213 pp.

The Distribution of Stoneflies (Insecta: Plecoptera) of the Salt River, Kentucky[1,2]

David S. White
Department of Biology and Water Resources Laboratory,
University of Louisville, Louisville, Kentucky 40208

Abstract

As part of a preimpoundment study for Taylorsville Lake in the Salt River, Kentucky, 2,932 adult and 1,375 nymphal stoneflies were collected from August 1970 to July 1971. Annotations are given for the 12 species that represent 5 families and 8 genera. Special emphasis was placed on a study of the life history for *Isoperla burksi*, including stomach analysis and fecundity.

Introduction

To understand the stream ecosystem, the combinations of organisms and the interactions of all communities must be examined as to the roles they play (Krumholz and Neff 1970). Among the benthic forms, the stoneflies constitute a major component of the food web, and an accurate list of the species, their abundance, distribution, and life histories is essential to interpreting the results of any changes that might occur in a stream ecosystem. In conjunction with a preimpoundment study for Taylorsville Lake in the Salt River Basin (Krumholz 1971, Krumholz and Neff 1972, Neff and Krumholz 1973) the benthic fauna of the area was surveyed from 1968 through 1972. As part of that survey, Woodling (1971, unpublished master's thesis, University of Louisville, Louisville, Kentucky) studied the benthic fauna and water quality of Brashears Creek, a major tributary to the Salt River, during 1969 and 1970. The present paper is a summary of our information on the plecopterans of both the Salt River and Brashears Creek during the study period.

Many aspects of the life histories of the stoneflies found in the Salt River Basin have been reported by Needham and Claassen (1925), Claassen (1931), Frison (1929, 1935, 1942), and Harden and Mickel (1952). An exception is *Isoperla burksi* Frison, which is quite common throughout the stream system. Thus, special attention has been given to food habits and fecundity for that species.

Acknowledgments

I wish to thank the personnel of the Water Resources Laboratory for assisting in collecting the benthic samples, and especially Vincent Resh, Bruce Wilson, and Tom Weber for their diligence in making the blacklight collections. I am particularly grateful to Dr. William E. Ricker, Fisheries Research Board of Canada, and Dr. Paul H. Freytag, University of Kentucky, for their determinations of the stoneflies. I also thank Dr. Louis A. Krumholz and Dr. Stuart E. Neff, Water Resources Laboratory, University of Louisville, for reviewing the manuscript.

The Study Area

The study area, in central Kentucky, extends 94 miles on the Salt River and 22 miles on Brashears Creek (Fig. 1) and has been described in detail by Krumholz (1971), Krumholz and Neff (1972), and Neff and Krumholz (1973). Station numbers used in this paper correspond to those listed by Krumholz (1971), Krumholz and Neff (1972), and Neff and Krumholz (1973) that were sampled regularly for benthos and other materials.

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[2] Contribution No. 170 (new series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

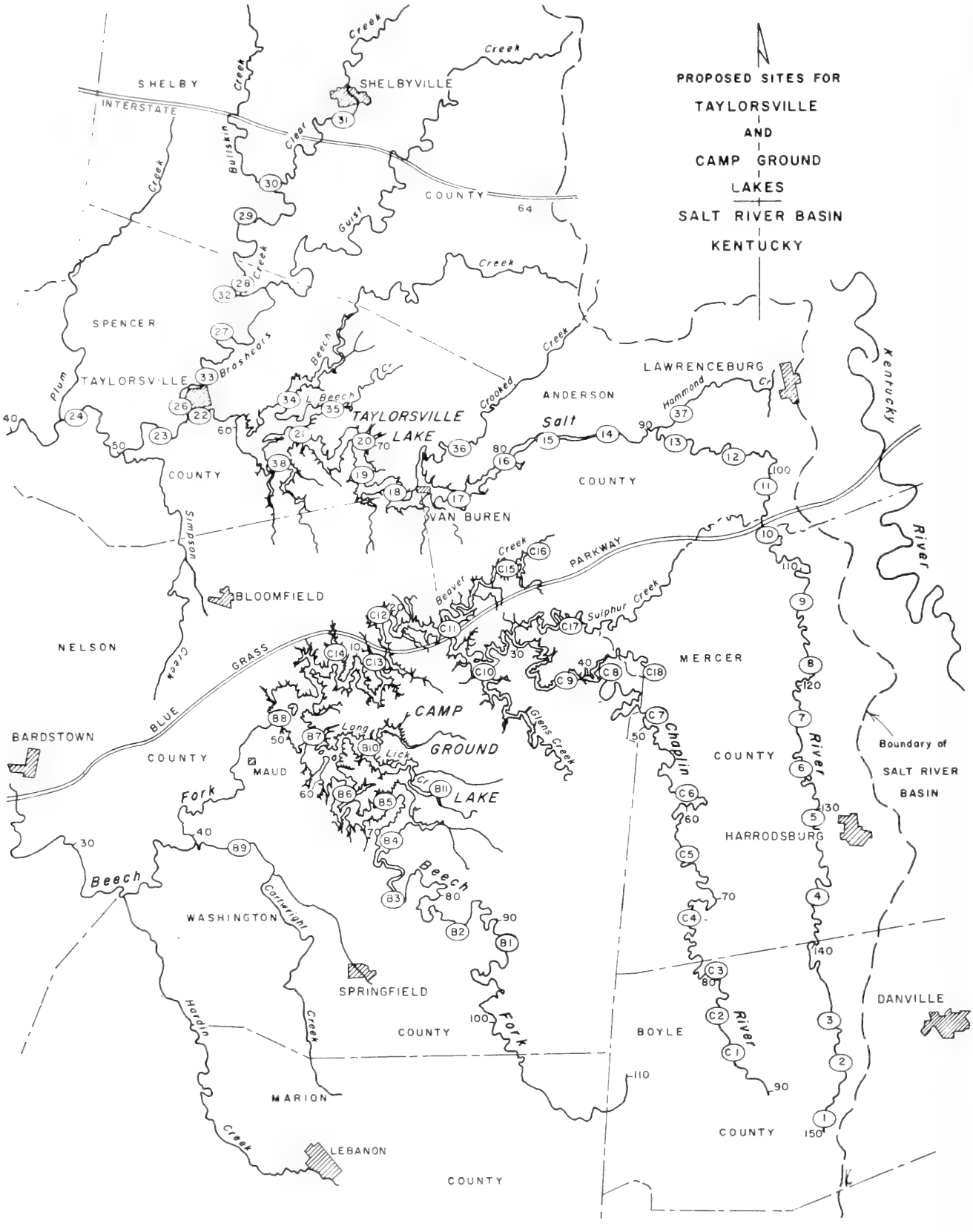

FIG. 1. Map of portions of the Salt River and Beech Fork showing the areas to be impounded and the locations of the permanent collecting stations. (From Neff and Krumholz 1973).

Upstream from Station 13, the Salt River will remain much as it is today and will not be flooded by impoundment for Taylorsville Lake. The bottom materials at these stations are primarily mud on limestone bedrock with scattered areas of sand, gravel, and rubble supporting some emergent vegetation. Stations 15 through

21 will be inundated permanently, and Station 14 is likely to be flooded at least part of each year. Bottom materials at those stations consist of bedrock, sand, gravel, and larger stones, and there are extensive beds of water willow *Justicia americana* (L.) Vahl from late spring through fall. Stations 22 and 23 are below the damsite and the bottom materials are similar to those upstream.

Brashears Creek enters the Salt River below the proposed damsite approximately 0.5 mile above Station 23. The bottom of Brashears Creek is much like that in the Salt River and also supports large stands of water willow. An intermittent tributary, Station T, that enters Brashears Creek from the west between Stations 26 and 33, was sampled when water was present. There, the streambed is similar to that in Brashears Creek.

The beds of water willow were an important physical feature of the study area, and particular attention was given to sampling those areas. During the summer, their growth effectively channelized many parts of the stream, giving it a braided appearance. The massive root systems limited shifting of the sand and gravel bars during periods of high water especially in the winter and spring months. The submerged root masses have been shown to provide an excellent winter refuge for many of the nymphs and larvae of the various aquatic insects (Woodling, unpublished master's thesis).

METHODS

Several hundred collections of nymphs were made using a Surber square-foot sampler and a 1-m wide "qualitative seine" made of nylon bobbinet (#0 grit cloth). The Surber sampler was used primarily in the riffle areas while the qualitative seine facilitated collection in the peripheral areas such as mudbanks and emergent vegetation.

Adults were collected through extensive weekly blacklighting from March through October 1971. Examination of tree trunks,

TABLE 1.—OCCURRENCE OF STONEFLIES AT 16 DIFFERENT STATIONS IN THE SALT RIVER AND BRASHEARS CREEK, KENTUCKY (SEE FIG. 1 FOR STATION LOCATIONS)

	Salt River Stations										Brashears Creek Stations							Nymphs	Adults
	2	3	4	7	13	14	16	17	22	23	T	26	33	28	29	30			
Nemoura nigritta						×	×	×	×	×						×		70	5
Allocapnia vivipara	×		×	×		×					×		×	×	×	×		242	274
Allocapnia forbesi												×	×					0	3
Brachyptera fasciata												×		×		×		6	2
Taeniopteryx burksi									×	×					×	×		7	9
Taeniopteryx parvula										×								6	1
Isoperla burksi					×	×	×	×	×	×			×	×	×	×		320	48
Isoperla clio						×			×	×			×	×	×	×		22	9
Isoperla nana				×		×			×	×						×		51	3
Acroneuria arida						×	×	×	×	×			×	×	×	×		219	356
Perlesta placida			×	×	×	×	×	×	×	×		×	×	×	×	×		308	2,189
Neoperla clymene					×				×	×				×	×	×		124	33
Totals	1	1	2	3	3	7	4	4	8	9	2	4	7	7	7	10		1,375	2,932

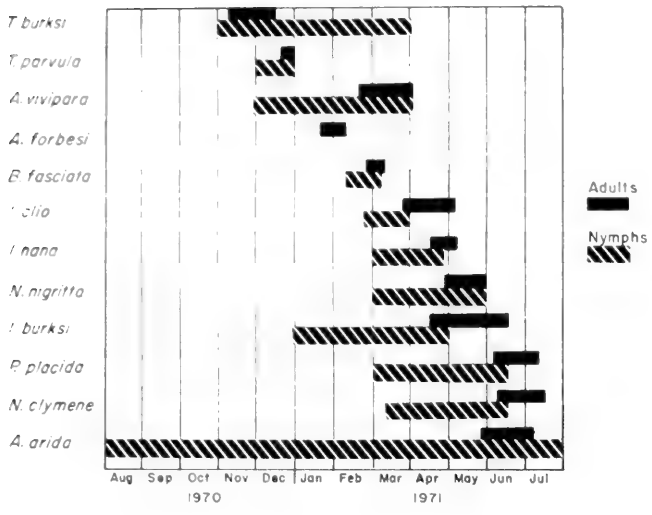

FIG. 2. Seasonal distribution of nymphs and adults of 12 species of stoneflies in the Salt River and Brashears Creek, Kentucky.

rocks, and bridge abutments yielded many adult specimens, and sweeping emergent and littoral vegetation proved effective, especially in collecting the winter and early spring forms. Where possible, nymphs and adults were identified and sexed using the guides of Needham and Claassen (1925), Claassen (1931), and Frison (1935, 1942).

THE STONEFLIES

During the study period, 1,375 nymphal and 2,932 adult stoneflies were collected from the 16 stations, and represented 5 families, 8 genera, and 12 species (Table 1). The seasonal distribution of nymphs and adults in those collections is shown in Fig. 2.

NEMOURIDAE

Nemoura nigritta group.—Seventy nymphs of this group were collected from March through May in the deeper, slower riffles from 5 stations in the lower Salt River and from a single station at the source of Brashears Creek just below the confluence of Bullskin and Clear creeks (Table 1, Fig. 2). Most were found on the larger stones though some were taken from the submerged water willow roots.

The adults, 1 male and 4 females, were found under the bark of fallen trees near the water's edge. The emergence period was very short; it began in early March and probably did not extend beyond 10 June.

CAPNIIDAE

Allocapnia vivipara (Claassen).—*A. vivipara* was the most abundant winter stonefly and the third most abundant stonefly in our collections; 242 nymphs were collected from 5 of the upper 6 stations in the Salt River and from all 6 stations in Brashears Creek (Table 1). Nymphs and adults were taken in and near the slow, shallow riffles in the Salt River and along the entire length of Brashears Creek. The greatest abundance of *A. vivipara* in Brashears Creek, however, was in the uppermost 3 stations and in the intermittent tributary.

Adults were present from late February to early April (Fig. 2). The sex ratio was very close to 1:1. The males, however, began emerging about 2 weeks before the females and were taken on tree trunks as far as 50 m from the shore. The females, though mainly macropterous, usually were not far from the stream's edge.

Allocapnia forbesi Frison.—*A. forbesi* was represented only by 3 adult males, and was the least abundant of any stonefly in these collections. All were taken in early February at Stations 26 and 33, near the mouth of Brashears Creek (Table 1, Fig. 2).

TAENIOPTERYGIDAE

Brachyptera fasciata (Burmeister).—Six large nymphs were taken in late February from riffles at 3 stations in Brashears Creek where the water was deep and fairly slow (Table 1). Both adult females were collected on a gravel bar at Station 33 in early March (Fig. 2).

Taeniopteryx burksi Ricker and Ross.—*T. burksi* was the earliest of the winter fauna and appeared in the riffles in mid-November. Though not abundant, it was present throughout the winter in the lower stations of the Salt River and in the upper reaches of Brashears Creek (Table 1). As with *Brachyptera*, the nymphs were found in the deeper, slower areas of the

riffles especially near the beds of water willow.

Adults, 7 males and 2 females, were taken under stones along the streambeds, and were collected only in November and December; however, they probably were present through early April (Fig. 2).

Taeniopteryx parvula Banks.—Six large nymphs were taken in December from the root masses of the water willows only at Station 23 in the Salt River just downstream from the mouth of Brashears Creek (Table 1). A single adult was taken on a sandbar at the same station.

Perlodidae

Isoperla burksi Frison.—*Isoperla burksi* was the fourth most abundant stonefly in our collections. Nymphs of *I. burksi* were more abundant than any other nymphs in the collections and were collected at 10 stations, especially in the riffles of the lower Salt River and throughout Brashears Creek from January to April (Table 1, Fig. 2). Of the 5 instars noted, the first 2 were found mainly among the roots of water willow. The larger individuals were most abundant in the open areas of the riffles. A measurable difference in size between males and females was noted in the 3 larger instars with the females becoming progressively larger until the difference in size was no greater than 0.2 mm prior to emergence. Nymphal females outnumbered males slightly more than 2:1.

Stomach analysis of 21 nymphs of different sizes showed *I. burksi* to be both carnivorous and cannibalistic, as are many other members of the genus. No nymph examined contained more than 1 organism in its stomach. All prey was consumed whole with no preference as to whether they were ingested headfirst or tailfirst. Of the 21 stomachs, 7 were empty, 8 contained chironomid larvae, 4 contained ephemeropteran nymphs, 1 contained a *Perlesta* nymph, and 1 an *I. burksi* nymph.

Adults began emerging in very late April and were present until the middle of June. They showed virtually no attraction to the blacklight, and only 1 was taken by that method during the entire emergence period. In late April and early May, adults were found under pieces of driftwood and bark scattered along the shore. Adults in late May and June were taken by sweeping the emergent water willow. The females collected in that manner outnumbered the males by slightly more than 2:1, the same sex ratio exhibited among the nymphs in our collections.

As indicated by the results of sweeping, mating and egg deposition took place during the day. Even though egg deposition was not observed, several females taken from the water willow deposited egg masses on the sides of the collecting jars. Egg counts from 10 newly emerged females ranged from 257 to 409 with an average of 358.

Isoperla clio (Newman).—A few large nymphs were taken in February and March from 3 stations in the Salt River and 4 stations in Brashears Creek (Table 1, Fig. 2). No more than 1 or 2 were collected in each sample indicating that the species was widespread but not abundant. Adults were taken from late March through early May by sweeping emergent vegetation.

Isoperla nana (Walsh).—Nymphs were collected from the riffles in early March through the end of April from 4 stations in the Salt River and 1 in Brashears Creek (Table 1, Fig. 2); but two adult males were taken in early May from a sandbar at that station, and a third was taken in late April as it drifted into the bottom sampler.

Perlidae

Acroneuria arida (Hagen).—*A. arida* was the second most abundant stonefly in our collections. With a 2-year life cycle, *A. arida* was the only nymph present in the riffles throughout the year (Fig. 2), and was collected at 5 stations in the Salt River and 4 stations in Brashears Creek (Table 1). First-year nymphs began appearing in the riffles during April and were abundant

until October. Since only a few specimens were taken from December through March, it was assumed that the nymphs either entered the submerged beds of water willow roots or were buried in the bottom sediments. In late March, nymphs reappeared at all of the lower Salt River stations and throughout much of Brashears Creek.

Emergence began in late May and continued through early July. *A. arida* was attracted to blacklight in large numbers.

Perlesta placida (Hagen).—*P. placida* was the most abundant plecopteran taken and made up more than half the total number of stoneflies in the collections. Also, it was taken at all but 2 of the stations sampled, those being in the extreme upper reaches of the Salt River, where the only stonefly taken was *Allocapnia vivipara.* Nymphs were present in the riffles from March through the middle of June (Fig. 2), and their numbers in the collections were exceeded only by those of *Isoperla burksi.*

Adults of *P. placida* were present from the second week in June through the second week in July, and the individuals of this species made up nearly three-fourths of all adult stoneflies in the collections.

Neoperla clymene (Newman).—Nymphs were found at 4 stations in Brashears Creek and at 3 stations in the Salt River (Table 1). They first appeared in the riffles in early March and were present until the second week in July. *N. clymene* was the fifth most abundant stonefly in the collections.

Emergence began in early June and extended through the middle of July. A few specimens were attracted to the blacklight but most were collected on stones near the stream's edge and by sweeping littoral vegetation.

Discussion

Of the species collected, all except *Acroneuria arida* appeared to be univoltine, producing a single generation per year. The life cycle of *A. arida,* as has been noted for other *Acroneuria* (Claassen 1931, and Harden and Mickel 1952), requires 2 years. All 12 species would be classified nonactive first instar or intermediate (Hynes 1961).

Of the 12 species in the collections, no more than 10 were collected at any station (Station 30 at the source of Brashears Creek), and at Stations 2 and 3 in the upper Salt River, only a single species was collected (Table 1). Nine species were collected at Station 23, 8 were present in the collections from Station 22, and there were 7 species in the collections from each of 4 stations, Station 14 in the Salt River and Stations 28, 29, and 33 in Brashears Creek. No more than 4 species were taken in the collections from the other 9 stations.

No species was taken at all 16 stations (Table 1), but specimens of *Perlesta placida* were collected at 14 stations, specimens of *Allocapnia vivipara* were taken at 11 stations, *Isoperla burksi* at 10 stations, *Acroneuria arida* at 9 stations, *Isoperla clio* and *Neoperla clymene* at 7 stations, and the *Nemoura nigritta* group at 6 stations. None of the others was taken at more than a third of the stations, and *Taeinopteryx parvula* was collected only at Station 23 just below the confluence of Brashears Creek and the Salt River.

With the exception of *Perlesta placida* and *Allocapnia vivipara,* all species were collected only at stations containing substantial beds of water willow. The water willow affords protection for the long inactive stages and for the smaller instars which were often collected by sampling in and around the root beds. Water willow provides a site for mating and egg deposition by adults of the late spring and summer such as the *Nemoura nigritta* group, *Taeniopteryx burksi,* and *Isoperla burksi.* Water willow is not necessary for *Perlesta placida,* but where this vegetation is present, it is used as a site for mating and egg deposition. *Allocapnia vivipara* is an inhabitant of small and intermittent streams, as often is *P. placida* (Frison 1929, 1935), and was found only in Brashears Creek and the portions of the

Salt River upstream from the proposed Taylorsville Lake.

Since the majority of the species were collected within or near the beds of water willow, any changes in the distribution of that vegetation brought about by the impoundment of Taylorsville Lake might have a direct effect on the abundance and distribution of these species in the Salt River.

As pointed out earlier, nymphs of *Acroneuria arida* were the only larvae present throughout the year (Fig. 2), since that species was the only one in our collections that had a 2-year life cycle. Nymphs of all other species were collected at different times from early November through mid-June (Fig. 2). Nymphs of *Taeniopteryx burksi* and *Isoperla burksi* were taken over periods of 6 months and the periods of collecting nymphs of other species ranged down to 2 months for *Brachyptera fasciata*, *Isoperla clio*, and *I. nana*. The only species for which nymphs were not collected was *Allocapnia forbesi*.

LITERATURE CITED

CLAASSEN, P. W. 1931. Plecoptera nymphs of America (north of Mexico). Vol. III. Thomas Say Foundation, College Park, Md. 199 pp.

FRISON, T. H. 1929. Fall and winter stoneflies, or Plecoptera, of Illinois. Ill. Nat. Hist. Surv. Bull. 18:340–409.

————. 1935. The stoneflies or Plecoptera of Illinois. Ill. Nat. Hist. Surv. Bull. 20: 281–471.

————. 1942. Studies of North American Plecoptera with special reference to the fauna of Illinois. Ill. Nat. Hist. Surv. Bull. 22: 233–355.

HARDEN, P. H., AND C. E. MICKEL. 1952. The stoneflies of Minnesota (Plecoptera). Univ. Minn. Agric. Exp. Sta. Tech. Bull. 20:1–84.

HYNES, H. B. N. 1961. The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. 57:344–388.

KRUMHOLZ, L. A. 1971. A preliminary ecological study of areas to be impounded in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. No. 43:1–16.

————, AND S. E. NEFF. 1970. The freshwater stream, a complex ecosystem. Proc. 5th Ann. Water Res. Conf. 6:163–174.

————, AND ————. 1972. A preliminary ecological study of areas to be impounded in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. No. 48:1–25.

NEEDHAM, J. G., AND P. W. CLAASSEN. 1925. A monograph of the Plecoptera or stoneflies of America north of Mexico. Thomas Say Foundation Bull. Entomol. Soc. Amer. 2: 1–397.

NEFF, S. E., AND L. A. KRUMHOLZ. 1973. A detailed investigation of the sociological, economic, and ecological aspects of proposed reservoir sites in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. No. 67:1–64.

Helminth Parasites of the White Sucker (Pisces: Catostomidae) in the Kentucky River Drainage

Glenn White And John P. Harley
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

The following helminths were recovered from 100 white suckers (*Catostomus commersoni*) from the Kentucky River drainage system: Acanthocephala, *Acanthocephalus jacksoni* and *Octospinifer macilentus*; Trematoda, *Clinostomum marginatum*, *Neascus* sp., *Phyllodistomum lysteri*, *Plagioporus serotinus*, and *Triganodistomum attenuatum*; Cestoidea, *Glaridacris catostomi*, *Hunterella nodulosa*, and *Monobothrium hunteri*; and Nematoda, *Contracaecum* sp. and *Philometra cylindracea*. *Octospinifer macilentus*, *P. serotinus*, *M. hunteri*, *Contracaecum* sp., and *P. cylindracea* are new state records. *Philometra cylindracea* is also a new host record.

Introduction

As stated in a previous paper (Bauer and Harley 1973), the helminth parasites of Kentucky fishes have, overall, been grossly neglected when compared with data from other states. A review of the literature indicates that only 2 published works exist on the parasites of the white sucker *Catostomus commersoni* Lacépède in Kentucky: Aliff (1973, unpublished doctoral dissertation, University of Kentucky, Lexington, Kentucky) reported the digenetic trematode *Lissorchis attenuatum* and White and Harley (1973) reported the acanthocephalan *Acanthocephalus jacksoni*, the trematodes *Clinostomum marginatum* and *Neascus* sp., and the cestode *Glaridacris catostomi*.

As a result, it was felt that a more complete study of the parasites should be done on the white suckers in Kentucky. Secondarily, *C. commersoni* was chosen for study because it is considered a nonsport or "rough" fish and thus has been neglected in many studies.

Materials and Methods

Representative numbers of fish were collected from Boone (11), Eagle (19), Otter (14), Silver (13), and Tates creeks (14), the main channel of the Kentucky River (11), and Kentucky River Lock No. 3 (18). Collections were made over a 13-month period from May 1972 through June 1973.

Fish were either autopsied in the field or were transported alive back to the laboratory for autopsy. Internal organs were placed in separate Petri dishes of saline and teased apart. When recovered, cestodes, nematodes, and trematodes were placed in saline. Acanthocephalans were placed in distilled water to evert the proboscis.

Fixation and relaxation of nematodes were accomplished by dropping them in hot 70 percent ethyl alcohol. Cestodes were first relaxed in 4 percent chloretone (Hargis 1953) and then fixed in hot standard AFA solution. Trematodes were placed under a coverslip with slight pressure and flooded with hot AFA. The acanthocephalans were fixed in hot AFA.

Adult acanthocephalans and trematodes were stained with both Harris' hematoxylin and Mayer's paracarmine. Cestodes were stained only with Mayer's stain or placed in polyvinyl alcohol according to Hoffman (1954). All staining was regressive. Destaining, dehydration, and clearing were done by the standard techniques (Guyer 1953). Mounting, except for PVA, was done in permount.

Results and Discussion

Catostomus commersoni, the common white sucker of the Kentucky River drainage system, has a diverse parasite fauna. Twelve species of helminths were recovered (Table 1). These represented all the major taxa of animal parasites in fishes.

TABLE 1.—NUMERICAL ANALYSIS OF PARASITES OF *CATOSTOMUS COMMERSONI* INCLUDING NEW HOST AND STATE RECORDS. ONE HUNDRED FISH WERE AUTOPSIED. IMM DESIGNATES IMMATURE WORMS

Parasite	% infested	Mean intensity of infestation	Total parasites	Location in fish	New host record	New state record
ACANTHOCEPHALA						
Acanthocephalus jacksoni	58	17	1,005	Intestine		
Octospinifer macilentus	2	6	12	Intestine		×
TREMATODA						
Clinostomum marginatum (Imm)	7	3	19	Fins, musculature, mouth, gill arches		
Neascus sp. (Imm)	11	59	644	External surface		
Phyllodistomum lysteri	4	5	19	Urinary bladder		
Plagioporus serotinus	10	73	729	Intestine		×
Triganodistomum attenuatum	2	3	6	Intestine		
CESTOIDEA						
Glaridacris catostomi	37	3	121	Intestine		
Hunterella nodulosa	8	11	87	Intestine		
Monobothrium hunteri	2	2	3	Intestine		×
NEMATODA						
Contracaecum sp.	9	2	14	Mouth (under epithelial layer)		×
Philometra cylindracea	2	3	6	Body cavity	×	×

The acanthocephalan, *A. jacksoni*, was the most abundant and widespread parasite found. Of the 5 trematodes recovered, the adult fluke *P. serotinus*, as well as the metacercaria of *Neascus* sp., were abundant. Four cestodes were found with *G. catostomi* being the one most commonly encountered. Nematodes were scarce, with only 2 species being found. However, *Contracaecum* sp. proved unusual in having cuticular papillae, and all were found under the epithelial layer of the mouth.

Five of the 12 parasites recovered constituted new range extensions, with Kentucky being a new locality record. In addition, *C. commersoni* is a new host record for *P. cylindracea* in the United States.

The drainage system as a whole appeared to be relatively unpolluted if the diversity and abundance of parasites were used as an index. Clean water is essential for the existence of molluscan and arthropod intermediate hosts, which helminths require for completion of their life cycles.

Two streams in this study deserve special note. Boone Creek lies in Fayette County, an area of rapid growth. This has led to the construction of 4 sewage treatment plants, 2 tertiary and 2 secondary, along this creek. Nevertheless, 10 of the 12 species of parasites were collected at this site. Eagle Creek was unusual because *O. macilentus* and *P. cylindracea* were collected here, but not from the other study areas in the Kentucky River drainage. This possibly could be a result of the piracy of Eagle Creek from the Ohio River during the Pliocene Epoch (Jillson 1949).

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LITERATURE CITED

BAUER, B. H., AND J. P. HARLEY. 1973. Intestinal parasites from two species of catfishes (Ictaluridae) from Lake Wilgreen in Kentucky. Trans. Ky. Acad. Sci. 34(3,4):55–56.

GUYER, M. F. 1953. Animal Micrology. Univ. Chicago Press, Chicago, Ill. 327 pp.

HARGIS, W. J. 1953. Chloretone as a trematode relaxer, and its use in mass collecting techniques. J. Parasit. 39:224–225.

HOFFMAN, G. L. 1954. Polyvinyl alcohol-fixative adhesive for small helminths and protozoans. Trans. Amer. Microsc. Soc. 73:328–329.

JILLSON, W. R. 1949. The piracy of Eagle Creek. Roberts Printing Co., Frankfort, Ky. 16 pp.

WHITE, G. E., AND J. P. HARLEY. 1973. Helminth parasites of the common white sucker, *Catostomus commersoni*, from Lake Wilgreen in Kentucky. Trans. Ky. Acad. Sci. 34(3,4): 53–54.

A New Coding System for Hardshelled Turtles

Carl H. Ernst
Department of Biology, George Mason University, Fairfax, Virginia 22030
Lexington, Kentucky 40506

Mary Faith Hershey, and Roger W. Barbour
Thomas Hunt Morgan School of Biological Sciences, University of Kentucky,

Several systems of marking and coding freshwater and terrestrial hardshelled turtles for further study have been proposed (Bogert 1937, Cagle 1939, Kaplan 1958, Pough 1970). Unfortunately, all have disadvantages which may make them impractical. Probably the best method for marking large numbers of wild turtles for future identification in capture–recapture studies is by notching the shell. It is the cheapest method and involves little time and few tools (Ernst 1971).

The coding system of Cagle (1939) for notching has been used in most turtle studies; however, it is complicated and confusing. In Cagle's system, the marginals are numbered 1 to 12 from anterior to posterior on each side of chelydrid, emydid, and testudinid turtles and 1 to 11 in kinosternid turtles. The positional number of the notched marginal is then recorded. A comma is used to separate those on a single side of the carapace, and a hyphen separates the left and right sides. For example, turtle 1, 8-2, 9 had the first and eighth left marginals notched and the second and ninth on the right side. This system allowed a total of 2,516 combinations by using up to 4 notches.

An easier and less confusing system is one with the notched marginals or certain plastral scutes coded so turtles can be numbered consecutively. This is done by assigning numerical values to certain carapacial marginals and the gulars and anals of the plastron. In chelydrid, emydid, and testudinid turtles marginals 1, 2, 3, 8, 9, 10, 11, and 12 on the left side of the carapace may be coded as 1, 4, 10, 40, 100, 400, 1,000, and 4,000, respectively, and the same marginals on the right side as 2, 7, 20, 70, 200, 700, 2,000, and 7,000 (Fig. 1). By adding the numerical values of the notched marginals, one arrives at the number of the specimen. For example, a turtle with notches on the second left marginal and tenth right marginal is 704. This system allows up to 999 turtles to be coded without making more than 6 notches per turtle, and 9,999 without more than 8 notches. If 10,000 or more turtles are to be marked, the plastron may be used; the left gular may be coded as 10,000, the right gular as 20,000, the left anal as 40,000 and the right anal as 70,000 (Fig. 1). It is doubtful if an investigator could ever use up all of the possible combinations in this system, and it can be applied to any number of different species concurrently.

Kinosternid turtles have only 11 marginals on each side of the carapace and the above system must be abbreviated for them. The corresponding left marginals can be coded as 1, 4, 10, 40, 100, 400, and 1,000, respectively, and those on the right at 2, 7, 20, 70, 200, 700, 2,000. If more than 3,999 turtles are to be marked, the plastron can again be used. Since some kinosternids have no more than a single gular scute, the humerals can be used instead with the left humeral coded as 4,000, the right humeral as 7,000, the left anal as 10,000 and the right anal as 20,000.

If large *Chelydra serpentina* or *Macroclemys temminckii* are to be marked, problems will arise during the notching process. A vicious tempered chelydrid with its powerful jaws and long neck can be restrained by allowing it to bite a length of rope and then tying the rope under the posterior edge of the carapace so the head is held in.

The marginals at the bridge of the carapace and plastron, or at the junction of

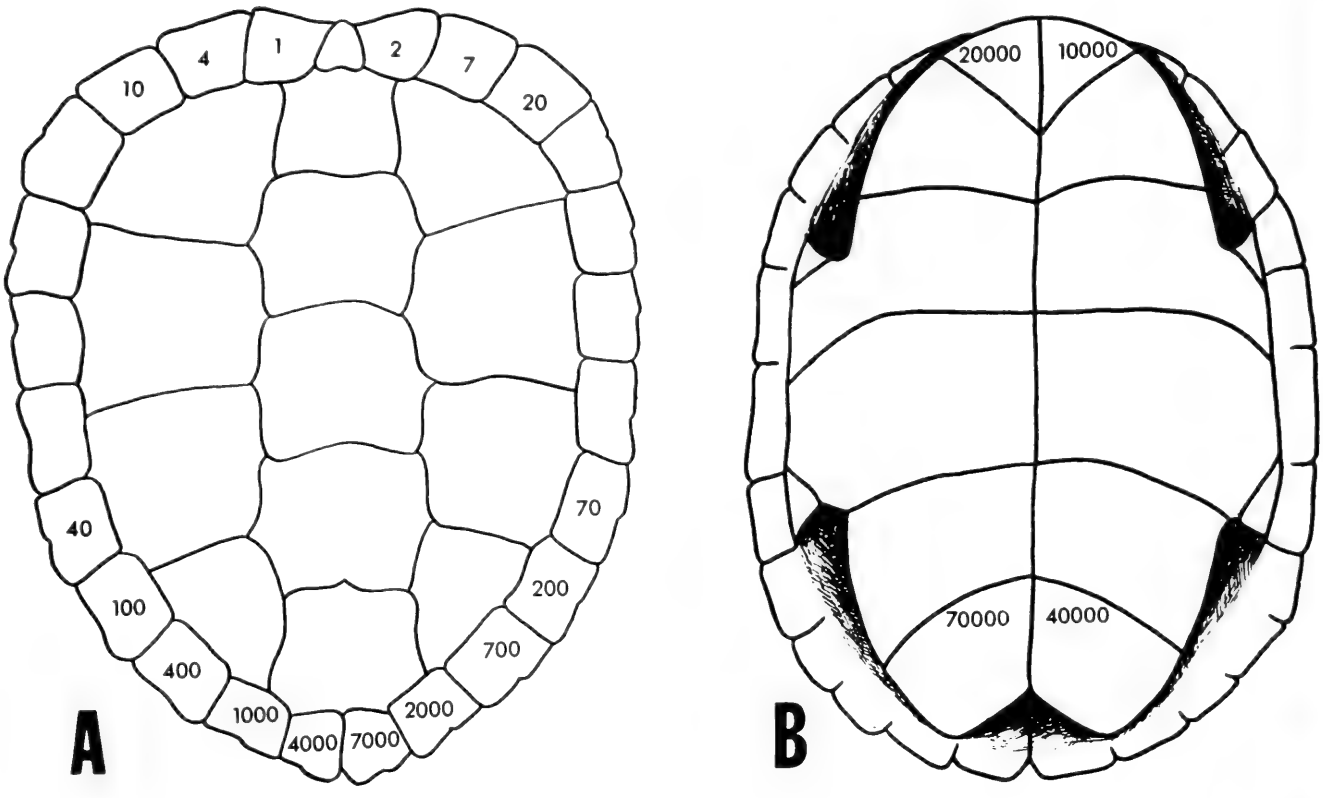


FIG. 1. A numerical coding system for notched hardshelled turtles (A = the carapace with the numerical codon for each suitable marginal; B = the plastron with the numerical value for each gular and anal).

the carapace and plastron in bridgeless species, should not be used because of the weakening of the shell at that point (this usually involves the fourth to seventh marginals).

The proposed numerical coding system is not difficult to memorize, requires few tools, and simplifies handling field data for large numbers of turtles. A field notebook with consecutively numbered entries can be kept with relative ease, and from it data can later be transferred to file cards or be computerized. The cards can be filed numerically with one card per turtle, and all entries for an individual can be entered chronologically on its card. The proper card is easily found for recording of additional data.

The numbers used for coding in this study are not the only ones possible and other systems may be worked out to allow coding of even larger numbers of turtles.

LITERATURE CITED

BOGERT, C. M. 1937. Note on the growth rate of the desert tortoise, *Gopherus agassizi*. Copeia 1937:191–192.

CAGLE, F. R. 1939. A system of marking turtles for future identification. Copeia 1939: 170–173.

ERNST, C. H. 1971. Population dynamics and activity cycles of *Chrysemys picta* in southeastern Pennsylvania. J. Herpetol. 5:151–160.

KAPLAN, H. M. 1958. Marking and banding frogs and turtles. Herpetologica 14:131–132.

POUGH, F. H. 1970. A quick method for permanently marking snakes and turtles. Herpetologica 26:428–430.

Decay and Its Prevention in Natural Stone

K. Lal Gauri
Geology Department, University of Louisville, Louisville, Kentucky 40208

Abstract

In our studies on a variety of natural building stones, we have observed 2 basic types of profiles of weathering. In highly compact rocks such as marble, the zone of weathering is characterized by a reduced specific gravity and augmented capillarity. Here, the texture of the zone of weathering is quite distinct relative to the texture of the parent material. In less compact rocks such as limestone, the pore space in the zone of weathering becomes plugged due to the recrystallization of salts obtained by the solution of the parent rock. The effect of continued weathering of all these stones is the surface reduction of objects which leads to destruction of ornamentation and surface relief. Using industrial polymers, methods of impregnation have been given which, by reducing water transport into the stone, have greatly minimized the effect of weathering agents.

Introduction

The deterioration of natural stone due to atmospheric attack is vividly exposed in the ruins of the Coliseum of Rome and in the Parthenon of Athens. Several centuries of atmospheric attack was essential to disintegrate those structures. With the increasing amounts of pollutant gases in the atmosphere contributed by the burning of fossil fuels, the deterioration of stone objects is now continuing at an accelerated pace. This paper is designed to present several aspects of stone deterioration such as modification of properties of weathered stone, laboratory methods of studying such properties, and decay rates of stone exposed to concentrated artificial atmospheres generated for accelerated weathering. Finally, certain methods of treatment are presented to retard the deterioration of natural stone used for sculptural and structural purposes in objects of art and architecture.

Acknowledgments

This paper was written during my leave of absence from the University of Louisville and an engagement with Universal Restoration Inc., Washington, D. C. The Universal Restoration also provided the weathered Portland limestone specimens from the St. Paul's Cathedral, London. I am thankful to Universal and the University of Louisville for their resources and facilities made available to me for research on stone conservation.

Weathering of Stone

The stone exposed to the atmosphere for a period of time commonly develops a zone of weathering which possesses discrete structure developed by the alteration of the parent rock as shown in Figs. 1A and 1B. Fig. 1A symbolizes stone types in which the component grains of rock are compactly packed. Marbles, granites, etc. are examples of such rocks. The compaction in these rocks has resulted from high-pressure environment in which these rocks were buried in earth's interior. These rocks commonly possess less than 2 percent porosity. Fig. 1B symbolizes relatively loosely packed rock varieties in which the lithification has occurred from natural cements. Limestones, sandstones, etc. represent such varieties of rocks. These rocks commonly possess a higher porosity due to a relatively loose packing.

The zone of weathering in Fig. 1A is characterized by an acquisition of a thoroughly new texture relative to the texture of the parent material. The grain boundaries in the weathered zone have been obliterated. Solutions and recrystallizations have resulted in a reduction of grain size and in the formation of a multitude of small granules. The cleavage planes have been widened. All these

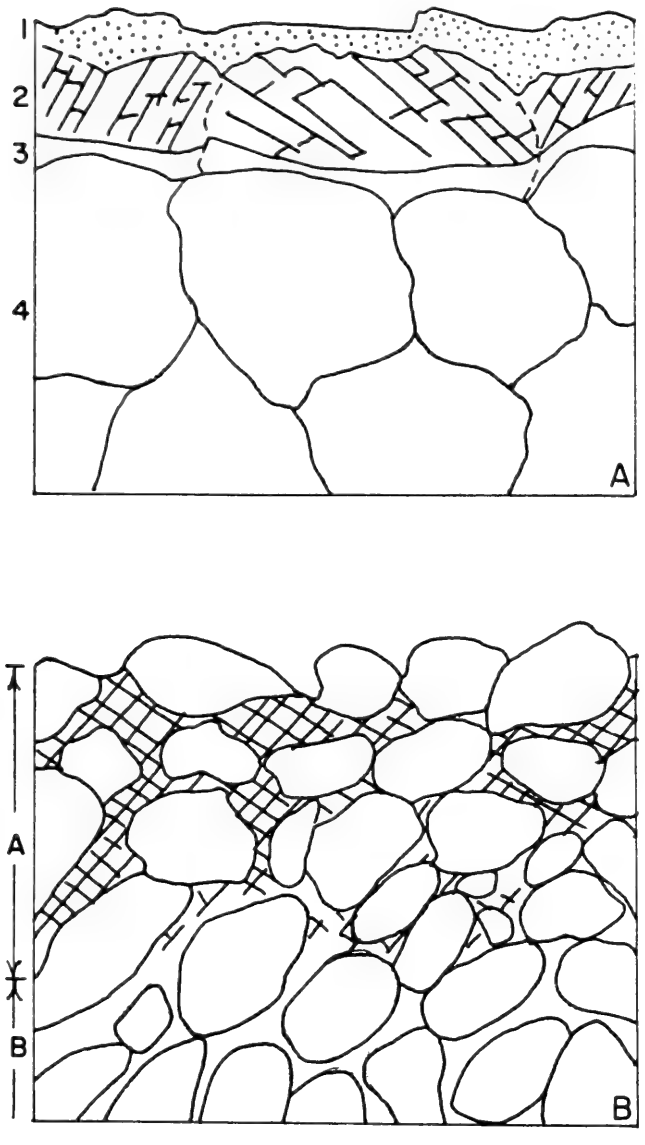


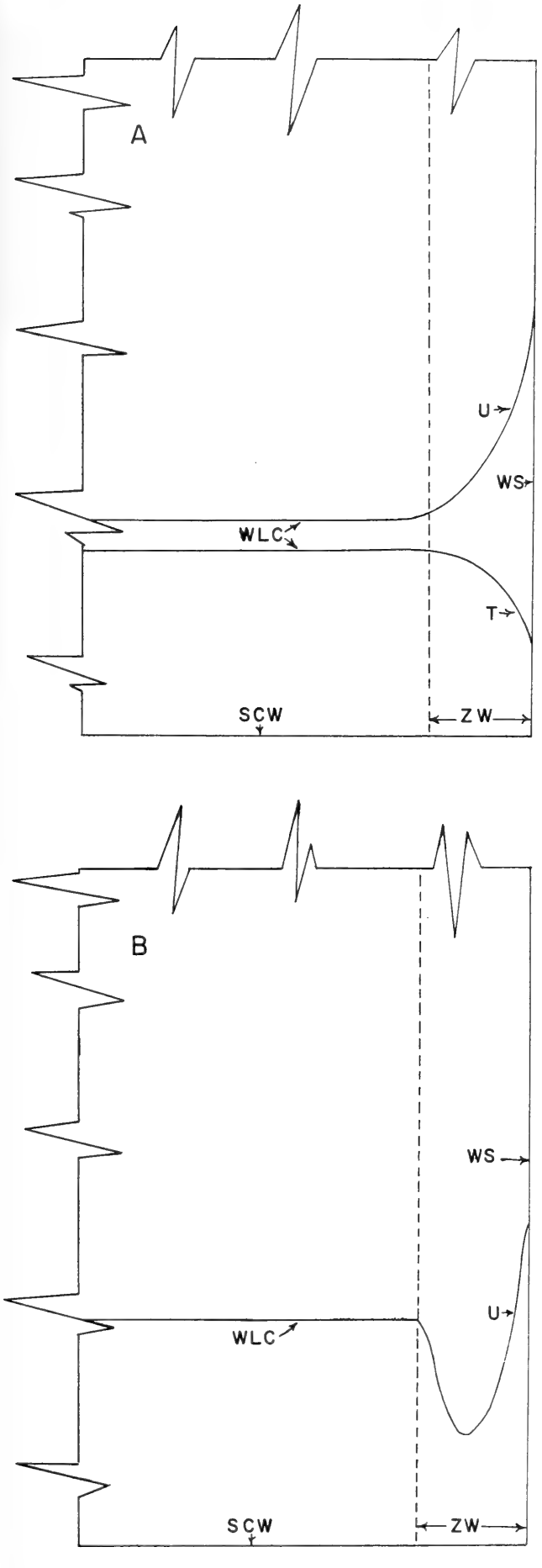
FIG. 1. Cross sections showing physical characteristics of the zone of weathering and its relationship to the parent rock. A. The specimen was obtained from a tombstone made from Carrara marble. The tombstone had been exposed in the Cave Hill Cemetery, Louisville, Kentucky, for nearly 100 years. The zone of weathering in this diagram consists of 1 + 2; 1 represents fine grained product of deterioration; In 2, solutions along the cleavage planes of individual grains have resulted in the widening of these planes and the boundaries between individual grains have become indistinct; 3 is the unweathered portion of calcite grains; 4 represents individual calcite grains which have not at all experienced the effects of weathering. Note that the zone of weathering is texturally completely distinct from the unweathered stone. B. The specimen was obtained from St. Paul's Cathedral where it had weathered for nearly 2 centuries. The specimen formed part of the base of one of the now dismantled urns which were put up in 1707. A in the diagram represents the zone of weathering characterized by complete or partial plugging of pores. Note the schematically represented reduction in grain size in the weathered zone. Note, also, that the texture of the weathered zone is quite similar to the texture of the parent rock (B).

changes in texture have led to an increased capillarity of the weathered zone as compared with the capillarity of the unweathered rock shown in Fig. 2A.

The zone of weathering shown in Fig. 1B is characteristically different from the zone of weathering in Fig. 1A. This zone (Fig. 1B) is not quite distinctly separated from the underlying unweathered rock, and the original texture of the rock is also maintained to a large degree. The differences that have come into existence relate mainly to plugging of pores in the near surface regions. This plugging is a result of crystallization of salts from solutions formed from chemical decay of the parent stone. As a result of plugging of pores, the curve of capillary rise (Fig. 2B) of water is quite distinct from such a curve shown in Fig. 2A. The higher capillarity towards the exterior of stone is due to surface roughness produced by a larger removal of material at intergranular surfaces.

The varied textural developments of the zone of weathering seem to generate from the porosity and permeability characteristics of the parent stone. In the case of limestone, large capillaries and pores permit an easy inward passage to solutions which have formed by the surface weathering. A part of these solutions is undoubtedly washed away. But from those parts of solutions which have entered the pore space, salts are crystallized. In the case of marbles, however, such inward movements of ions in solution are restricted due to capillary characteristics. Therefore, most of the solutions produced at the surface are removed by rainfall, etc. The balance of redistribution of materials resulting from solution and recrystallization is, in general, a continual reduction of surface which follows a reduced density and strength and an increased capillarity, porosity, and permeability of the weathered zone.

The determination of strength of the



weathered zone and that of horizons within this zone is difficult. Customarily, the compressive strength of materials is determined by simple engineering tools which are used to crush the material with a known force. Such strength determinations have little significance in the context of the weathered rock because the zone of weathering is extremely thin and because its strength is not uniformly distributed across its thickness. Therefore, indirect methods need to be established to determine the strength of rock at different levels within and beyond the zone of weathering.

Following initial studies by Miller (1965, unpublished master's thesis, University of Illinois, Urbana, Illinois) to establish relationship of Apparent Specific Gravity (ASG), Shore Scleroscope Hardness (Sh) with compressive strength (σ), Ullrich (in Ullrich unpublished master's thesis, University of Louisville, Louisville, Kentucky, 1971; and Gauri, Hagerty, and Ullrich 1972) determined ASG and Sh at different levels from surface towards depth of the stone for Carrara marble. The marble specimens were obtained from tombstones which had been weathered for about a century in the Cave Hill Cemetery, Louisville. Ullrich developed the relationship $\ln \sigma$ (ksi) $= 0.914 + 0.014$ (ASG)(S). The application of this derivation to unweathered calcareous rock provided significantly similar values for σ as compared with values obtained by actual compression tests.

←

FIG. 2. Capillary rise of water in a weathered stone. Fig. 2A and 2B represent specimens from Carrara marble and Portland limestone (see explanation of Fig. 1), respectively. Note that the water level in the zone of weathering in Fig. 2B is lower, due to pore plugging, than in the unweathered portion of the rock. Fig. 2A also shows (similar in 2B, but not shown) that an impregnation of the stone by polymer causes a reversal of the curve both in the weathered and the unweathered regions of the stone. SCW: surface in contact with water, T: Treated specimen, U: Untreated specimen, WLC: Water level due to capillarity, WS: Weathered surface, ZW: Zone of weathering.

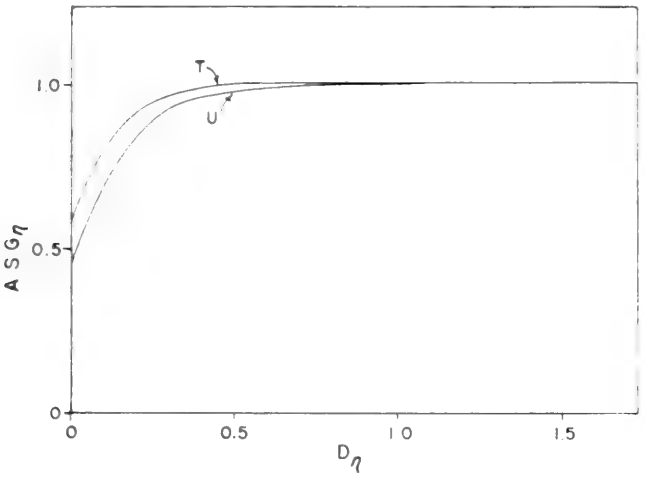


FIG. 3. Normalized (see text) Apparent Specific Gravity, ASG_n, versus Normalized Depth, D_n, in a weathered specimen of Carrara marble. T: Treated, U: Untreated. After Gauri, Hagerty, and Ullrich 1972.

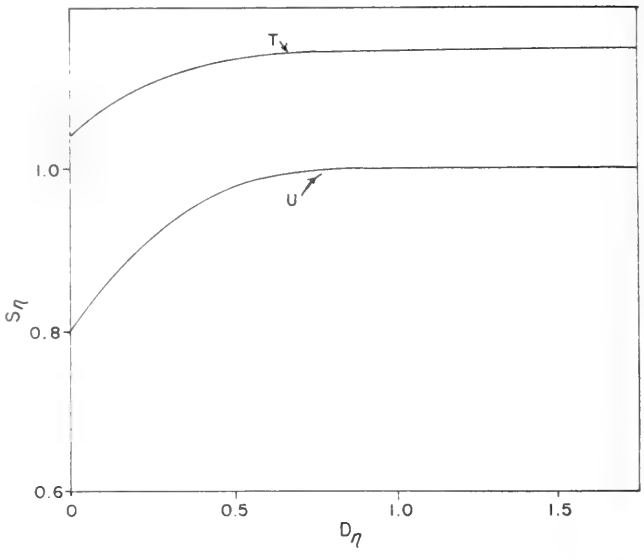


FIG. 4. Normalized (see text) Shore Scleroscope Hardness, S_n, versus Normalized Depth, D_n, in a weathered specimen of Carrara marble. T: Treated, U: Untreated. After Gauri, Hagerty, and Ullrich 1972.

To obtain comparable curves for different specimens, σ and the parameters which yielded it were normalized. For normalization, a constant factor for a given rock specimen, e.g., the thickness of the zone of weathering was made the denominator while the numerator, to determine the normalized depth, was the depth from surface at which a given value was determined. For instance, the thickness of the zone of weathering is 2 mm and the depth at which a given property, say ASG, is determined is 0.5 mm. The normalized depth, then, (D_n) is 0.5/2 mm = 0.25. In another example, say the Sh of nonweathered zone is 30 and the Sh at a given depth in the weathered zone is 15. The normalized Sh (S_n) at the given depth then is 15/30 = 0.5, i.e., 50 percent of the Sh of the nonweathered stone. At $D_n = 1$, the S_n, ASG_n, and σ_n will be 1.

The loss of ASG, Sh, and σ in the weathered region is shown in Figs. 3–5. It is evident that the weathered region of the marble has suffered up to 66, 55, and 20 percent reductions, respectively, in their compressive strength, specific gravity, and Shore hardness as compared with the unweathered regions of the marble.

THE PRESERVATIVE TREATMENT OF STONE

There are 2 basic approaches for the preservation of stone: those which change the chemistry of the stone so that the resultant substance is more resistant to atmospheric attack, and those which provide by means of impregnation of synthetic organic materials both protective coating and a cement between dislodged grains.

In the first approach, common materials of treatment have been solutions of hydroxides of calcium, barium, strontium, etc. These solutions are introduced into the stone. On reaction with atmospheric CO_2 or the CO_2 obtained by dissociation of media which accompany these solutions, insoluble carbonates of these cations are formed. These solutions are mostly ionic and the penetration of ions into the stone is only a few millimeters. Therefore, generally, they form consolidated crusts in the weathered regions of stone. Such crusts exfoliate due to continuing chemical and mechanical changes behind the treated regions.

In the second case, synthetic organic materials carrying curing agents are made to penetrate into the rock where they polymerize to consolidate the rock. Several factors impede the success of this treatment. These factors include the shallow penetration of mostly viscous organic preservatives, the sealing of pores which inhibit essential breathing of the stone and

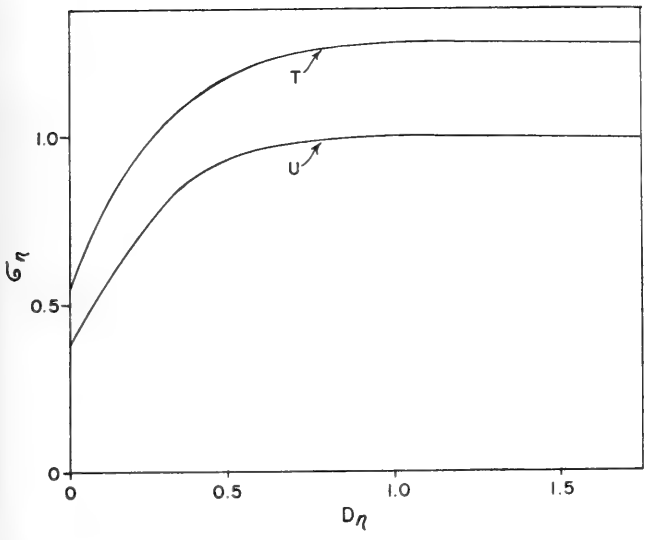


FIG. 5. Normalized (see text) Compressive Strength, σ_n, versus Normalized Depth, D_n, in a weathered specimen of Carrara marble. T: Treated, U: Untreated. After Gauri, Hagerty, and Ullrich 1972.

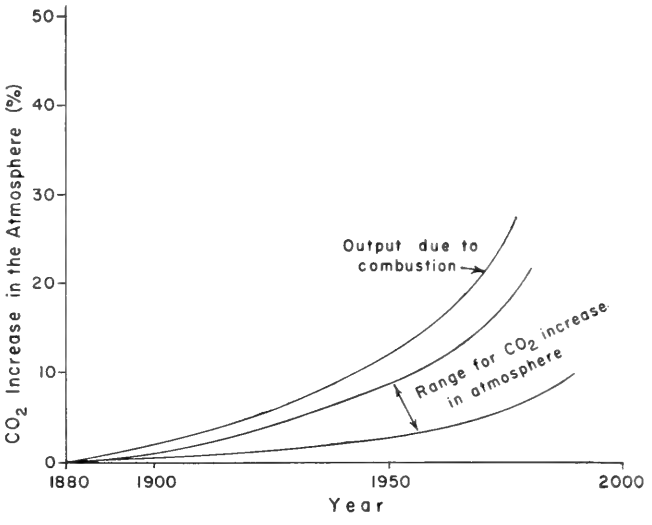


FIG. 6. Worldwide increase of the CO_2 content in the Atmosphere due to Fossil Fuel Combustion. After Bolin and Erickson 1959.

the difficulty of removing occluded impurities from the stone. In the following, a technique is redescribed (Gauri 1970) which mostly overcomes these difficulties.

The stone is first immersed in a solvent–water mixture or in the solvent or in a low concentration mixture of a polymer in the solvent. It is then transferred through increasing concentrations of polymer in the solvent. The first treatment permits the less viscous solution to penetrate to a greater depth while denser solution of subsequent applications remains in the shallower, weathered, depths of the stone. In this process of treatment, diffusion forces come into play by means of which higher density resin is exchanged for lower density resin to a depth dependent upon the pore size and the time of treatment. For diffusion, above successive applications are made to occur without a time lapse between the applications. After treatment, the impregnant polymerizes and thus imparts cementation between grains of both weathered and unweathered regions of the stone. This cementation also anchors the weathered region with the unweathered regions of the stone. The evaporation of the solvent from the impregnant leaves behind porosity which permits subsequent breathing of the stone. Because such resins are selected for treatment which have a good bond with the stone components, the films of the resin envelope the grains rather than forming pellets in the pore space. This is essential because grains of treated stone must be secluded from coming in contact with atmospheric gases and water which may enter the remaining pore space.

The result of the impregnation of the stone is that most of its physical characteristics which had altered due to weathering are now revisited. Figs. 3–5 show that the specific gravity, Shore hardness, and compressive strength are increased. The capillarity, porosity, permeability, and the water absorption on the other hand have significantly decreased. The restoration, rather the improvement of these properties over the properties of the original stone, enables the stone to resist future atmospheric attack.

The chemically active gases which decompose the stone are increasing in the atmosphere due to increments in the burning of fossil fuels. The burning of coals which contain sulfur results in high dosages of SO_2 emitted into the atmosphere. The city of Louisville is burning more than 4 million tons of coal annually for the production of gas and electricity only. This generates approximately 240,000 tons of SO_2; alternatively, at least 3,000 ppm SO_2

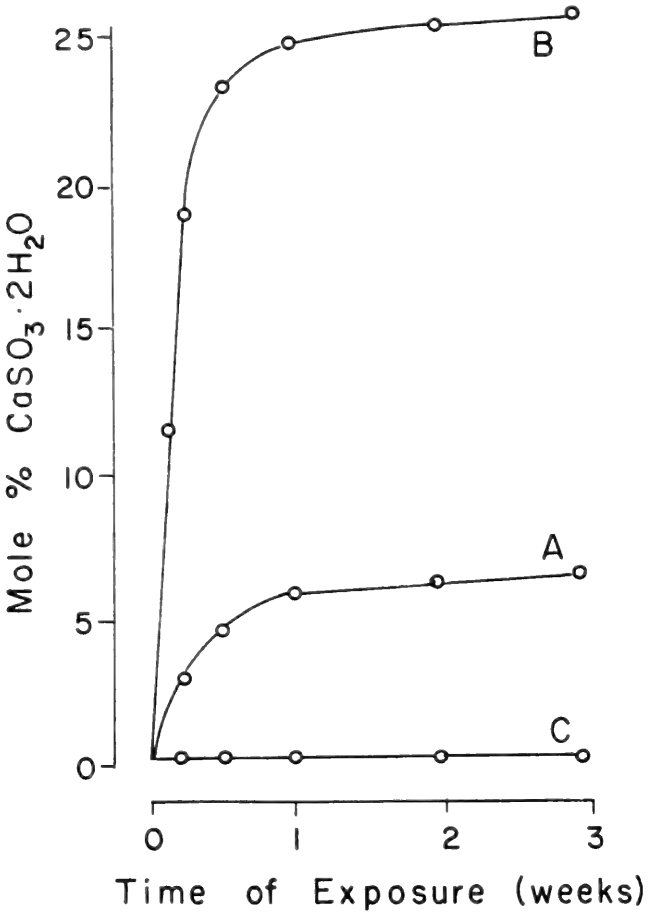


FIG. 7. SO_2 attack on Calcite in concentrated dynamic atmosphere. SO_2 concentration 700 ppm, Humidity > 80 percent, Flow 400 ml/min. The specimens were obtained from Green Mont, Vermont marble. A: control (untreated), B: treated with an Epoxy Resin (not all epoxy resin enhance Calcite–SO_2 reactivity), C: treated with a polyvinyl containing fluorine.

is being emitted into the atmosphere of this city. Recent studies on the rainwaters of the Eastern United States (Johnson and Reynolds 1972) indicate 4.3 mg/l of sulfate with an associated pH of 4.4. Similarly, the quantities of CO_2 have also considerably increased as a result of burning of fuels. Bolin and Erickson (1959, Fig. 6) have shown that the output of CO_2 due to combustion has increased more than 25 percent within the present century. As a result of attack of, primarily, these gases Loughlin (1931) estimated surface reduction of limestone at a rate of 1.57 mm in 50 years in New York City. The increased industrial activity has doubtlessly increased the surface removal rates of the carbonate rocks exposed to the ambient.

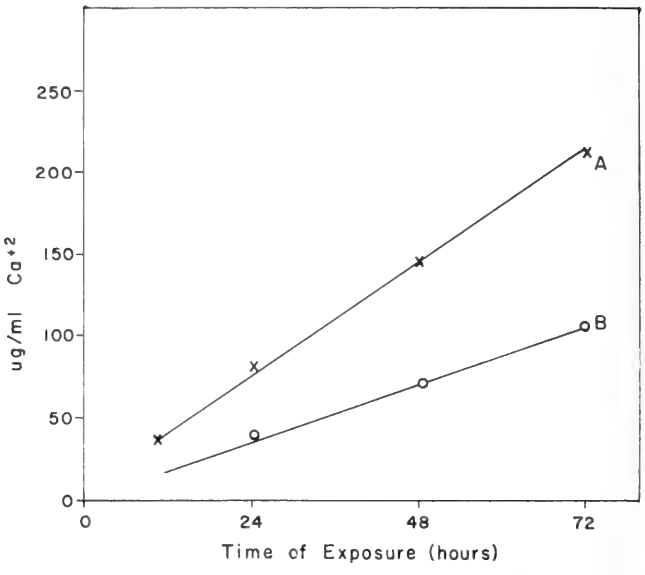


FIG. 8. CO_2 attack on Calcite in concentrated artificial dynamic atmosphere with a 2.27 percent mixture of CO_2 in air. Note that the treated specimen retarded the CO_2 attack as compared with the untreated specimen. After Tanjaruphan (unpublished master's thesis).

The following equations govern the reactions of CO_2 and SO_2 with calcite in the presence of moisture.

$$CaCO_3 + H_2O + CO_2 \leftrightharpoons Ca^{2+} + 2\,HCO_3^-$$

$$CaCO_3 \xrightarrow[H_2O]{SO_2} \begin{cases} CaSO_3 \cdot \tfrac{1}{2}\,H_2O + CO_2 \\ CaSO_3 \cdot 2\,H_2O + CO_2 \end{cases}$$

$$\xrightarrow[H_2O]{O_2} CaSO_4 \cdot 2\,H_2O$$

These reactions are so slow in nature that the reaction rates are difficult to study. We have, therefore, generated artificial concentrated atmospheres in the laboratory to accelerate the rates of reaction. Presently, we are using these gases individually for reactivity. We plan to study the effect of these gases when they attack stone collectively in the reaction chambers. The fact that collective reaction may be different than individual reactions seems logical because changes in reaction environments caused by a given gas reaction may suppress the reactivity of another reactant. Johnson and Reynolds (1972) have shown that sulfate content in water suppresses CO_2

reactivity with calcareous materials. In our later studies we also intend to include the reactivity of NO_2 with calcareous stone.

Our artificial atmospheres consist of mixtures of known quantities of reactive gases (CO_2, SO_2) and air passed at a given rate of flow through reaction chambers. For SO_2 reactions, the specimens are hung free in the reaction chamber and the humidity is controlled by several ways; such as bubbling the gas–air mixture through water and/or placing water at the bottom of the reaction chamber in which the specimens are freely suspended. For CO_2 reactions, the specimens are completely immersed in water through which gas–air mixture is bubbled. The concentration of CO_2 in water is maintained at a constant level by controlling the CO_2 partial pressure.

The reaction products of calcite and SO_2, namely, calcium sulfite and calcium sulfate are crystalline compounds. They lend themselves to quantitative analysis by x-ray diffraction. In practice, the integrated diffracted intensity, in counts, is measured 10 to 11° for sulfate, 27 to 28.8° for sulfite, and 28.8 to 30° for calcite in 2 θ values. These counts are compared with the counts obtained for corresponding 2 θ values obtained from calibrated samples to obtain percentages of given species of a compound formed as a result of SO_2 reaction.

The rate of reaction is determined by SO_2 concentration, the level of humidity and flow rate of the reacting atmosphere, and the particle size of the reactant stone. Higher humidity and SO_2 concentrations accelerate the reaction, slower flow rate and larger particle size decelerate it. In general, however, the pattern of reactions in any set of variable conditions remains the same as exemplified in Fig. 7. In the initial phase, the reaction is quite fast, but it soon attains a steady state beyond which the reaction ceases to proceed. The reason for such a steady state lies in the formation of calcium sulfite at the surface which acts as a protective coating against continued reaction. In nature, however, any calcium sulfite or sulfate that forms is washed away with the next rain. Thus, the plot of reaction for a natural stone would be a straight line, the slope of which is roughly determined in the very initial phases of the reaction.

A reaction proceeding under certain laboratory conditions may be augmented by the condensation of moisture on the surface of specimens. This moisture carrying absorbed SO_2 penetrates into the deeper regions of specimen, thus exposing larger areas to SO_2 attack. In specimens which had once attained a steady state in reaction chambers and were then wetted with water, a 100 percent transformation of calcite occurred at the surface as compared with a 15 mole percent sulfite formation in specimens which were exposed to otherwise most rigorous reaction conditions. One of the secrets of a successful treatment of stone is thus to use materials which are water repellant. The absence of moisture will not only chemically protect the stone, but also the mechanical stresses caused by freezing and thawing of water and the effects due to wetting and drying will be eliminated. Further, the damage due to increment of volume by hydration of salts such as sulfates and chlorides of sodium and calcium lodged as occlusions in the pore space of stone will also be averted.

Fig. 7 shows the effect of treatment by certain polymer species. It is obvious that certain polymers provide more protection than other polymers. Most interesting, however, is the fact that certain polymers enhance the rate of reaction as compared with the reactivity of untreated specimens.

For the study of CO_2–calcite reactions, the specimens were submerged in water through which a known concentration of CO_2 in air was passed. Tanjaruphan (1973, unpublished master's thesis, University of Louisville, Louisville, Kentucky) studied this reactivity as a function of Ca^{++} concentration of these waters determined by EDTA titration and atomic absorption. Fig. 8 represents the reaction rates of treated and untreated specimens. This study has revealed that the same polymers

are effective as protecting agents as those which considerably retarded SO_2–calcite reactivity.

CONCLUSION

This study has shown that effectiveness of protective treatments can be determined by laboratory techniques in a very short time. The conservators for objects of art now do not have to take a chance or to wait for years to see whether or not a treatment will be effective. A judicious selection of preservatives and proper application techniques can considerably prolong the life of precious art objects and provide greater strength to withstand the effects of gaseous pollutants and weather controlled mechanical stresses.

LITERATURE CITED

BOLIN, B., AND E. ERICKSON. 1959. Change in the CO_2 content of the atmosphere and sea due to fossil fuel combustion. pp. 130–142. *In*: B. Bolin (Ed.), "The Atmosphere and Sea in Motion," Oxford University Press, London.

GAURI, K. L. 1970. Improved impregnation technique for the preservation of stone statuary. Nature 228:882.

GAURI, K. L., D. J. HAGERTY, AND C. R. ULLRICH. 1972. Comparative physical properties of weathered impregnated and unimpregnated marble. Eng. Geol. 6:235–250.

JOHNSON, N. M., AND R. C. REYNOLDS. 1972. Atmospheric sulfur: its effect on the chemical weathering of New England. Science 177: 515–517.

LOUGHLIN, G. F. 1931. Notes on the weathering of natural building stones. Proc. Amer. Soc. Testing Mater. 3(11):759–767.

Mammals of Pulaski County, Kentucky

David J. Fassler
University of Kentucky, Somerset Community College, Somerset, Kentucky 42501[1]

Abstract

A survey of the native mammals of Pulaski County, Kentucky, was made between 15 January 1971 and 1 July 1973. During that period, 33 species of mammals were collected, 4 species were observed but not collected, and 13 species remain in questionable status. Notes on reproduction, morphology, distribution, and ecology are given for certain species.

Introduction

Few specific areas have been thoroughly studied to determine the status of the native mammalian fauna in the Commonwealth of Kentucky. The most notable study of any location was by Barbour (1951) on Big Black Mountain in Harlan County. Most other studies of mammalian distribution were aimed at a given genus or species. This summary of information on the mammalian fauna of Pulaski County is based on more than 300 specimens gathered from 15 January 1971 to 1 July 1973. The majority of those specimens are in my personal collection, or have been deposited at Morehead State University, Western Kentucky University, or Eastern Kentucky University.

Pulaski County is a politically defined area of 243 km^2 in south-central Kentucky. The Cumberland River, which bisects the southern part of the county, was dammed in 1951, to form Lake Cumberland. Elevations above mean sea level within the county range from 220 m at normal pool level of Lake Cumberland to 513 m on the summit of Green River Knob.

Geologically, the eastern portion of the county lies on the Cumberland Plateau, an area characterized by Pennsylvanian shales and sandstones. The western part of the county consists of Mississippian limestones. The eastern portion of the county is hilly; the western part is more gently rolling. A more detailed analysis of the county has been treated by Lewis (1974).

The county has a predominantly mixed mesophytic forest association (Oosting 1956). The county has acidic sandstone-derived soils in the east and alkaline limestone-derived soils in the west. Hemlock (*Tsuga canadensis*), pines (*Pinus* spp.), mountain laurel (*Kalmia* sp.), and buckeye (*Aesculus octandra*) are predominant in the sandstone areas, and hackberry (*Celtis occidentalis*) and black locust (*Robinia pseudo-acacia*) are predominant in the limestone areas. Beech (*Fagus grandifolia*), magnolia (*Magnolia grandiflora*), yellow poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), hickory (*Carya* spp.), and oaks (*Quercus* spp.) occur in both areas. Sycamore (*Plantanus occidentalis*) occurs throughout the county, but is typically hydrophytic. In those areas where the hardwood trees have been removed, the terrain usually is covered with stands of fescue (*Festuca* spp.).

Scientific nomenclature follows Barbour and Davis (1969) for the Chiroptera and Hall and Kelson (1959) for all other orders.

Acknowledgments

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[1] Current address: Prudential Insurance Company, 621 South 10th Street, Bozeman, Montana 59715.

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THE MAMMALS

Didelphis marsupialis (Kerr), opossum.

The opossum is found in all parts of the county and specimens were collected from 7 locations. A female killed in Somerset on 28 June 1972 contained 9 joeys, 56 mm in crown–rump length. A female captured on 16 April 1973 contained 9 joeys, which were weaned by 14 May 1973.

Sorex fumeus (Miller), smoky shrew.

A partially mutilated adult was obtained on 27 September 1971 at the Somerside Acres subdivision between Somerset and Burnside, having been caught by a house cat. The shrew presumably lived in the open fields near the subdivision. Moist areas such as those preferred by this shrew are not close to the subdivision.

Cryptotis parva (Say), least shrew.

Five least shrews, caught by house cats in the city of Somerset, were collected in March, July, October, and December. A female found on 3 July 1972 contained 5 embryos, 9 mm in crown–rump length. This shrew probably is common in open fields throughout the county.

Blarina brevicauda (Gapper), short-tailed shrew.

This shrew is frequently the prey of house cats. Specimens were collected during all months except January, February, and September. This animal is frequently confused with a young mole by the local residents.

Scalopus aquaticus (Linnaeus), eastern mole.

The eastern mole probably is ubiquitous in well-drained soils throughout the county. About 10 percent of my specimens contained patches of white on the venter.

Parascalops breweri (Bachman), hairy-tailed mole.

One badly mutilated, but identifiable, road-killed *P. breweri* was observed near Plato in northeastern Pulaski County.

Plecotus rafinesquii (Leeson), Rafinesque's big-eared bat.

Fassler (1971) reported this bat to be common in Pulaski County. Specimens have been collected at Sloan's Valley Cave, an unnamed cave 7.7 km east-southeast of Somerset, and at an abandoned house 3.2 km west-southwest of Ingle that was occupied by a nursery colony of more than 50 females with their young.

Nycticeius humeralis (Rafinesque), evening bat.

Fassler (1973) reported collecting of an adult male 3.2 km south-southeast of Jugornot on 18 April 1972.

Lasiurus borealis (Muller), red bat.

Red bats have been collected or observed throughout the year. On warm winter days, this animal can be seen flying about in the late afternoon. Davis and Lidicker (1956) reported similar winter behavior in this bat. A male red bat was found hibernating in an abandoned woodpecker hole near Gregory in adjacent Wayne County, Kentucky (Fassler 1974).

Lasiurus cinereus (Palisot de Beauvois), hoary bat.

Fassler (1972) reported finding a male hoary bat in Somerset on 13 November 1971. The specimen was unique because of its rarity in the Commonwealth and its late autumn arrival.

Lasionycteris noctivagans (Le Conte), silver-haired bat.

Barbour and Davis (1969) stated that the silver-haired bat is a common migrant in Kentucky during March and April. This species was observed in flight on 1 November 1972. On 14 March 1973, a nonpregnant female was found in a vertical

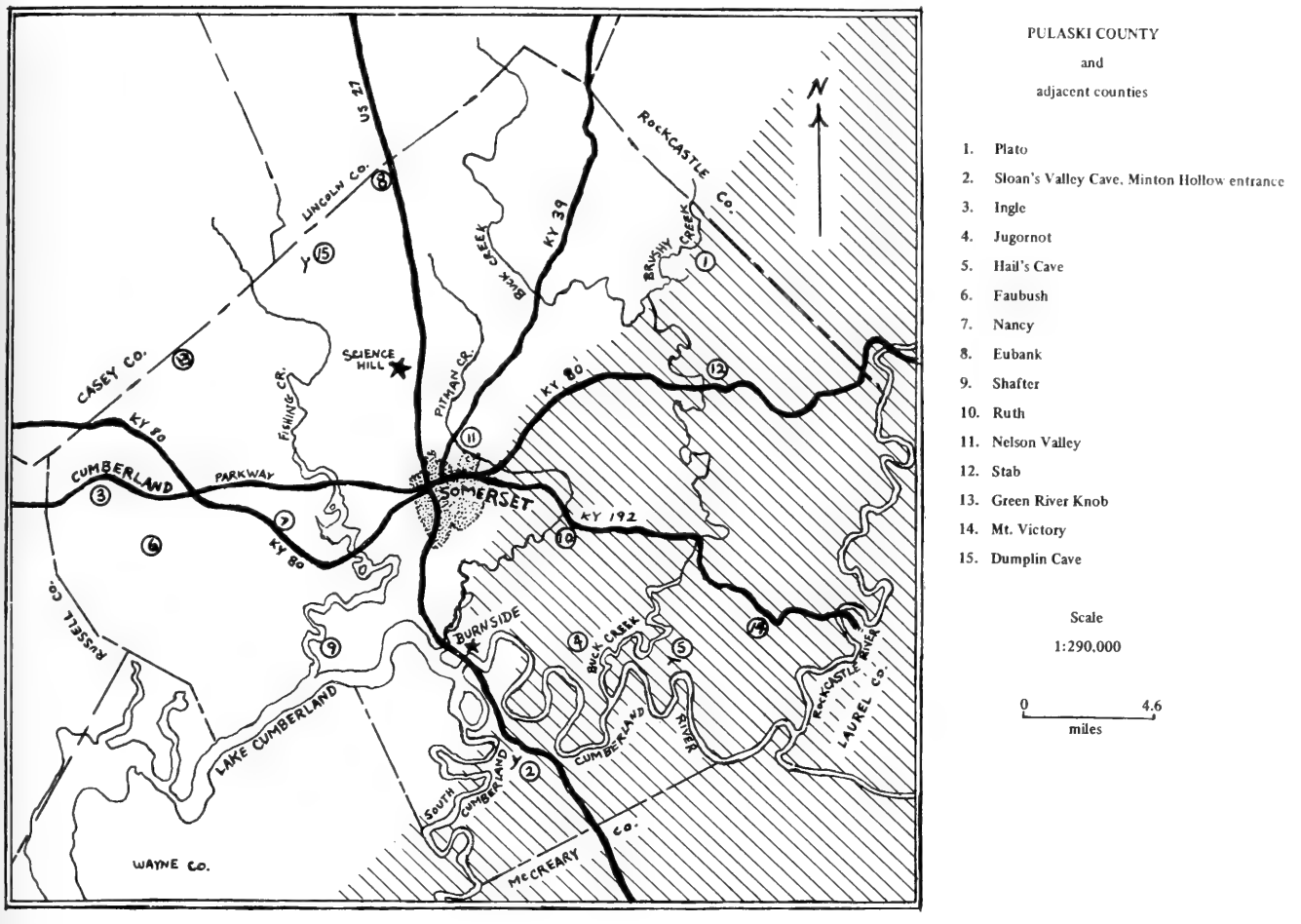

FIG. 1. Map of Pulaski County showing important physiographic features. The area of the Cumberland plateau is cross hatched.

crevice just inside Hail's Cave. On 15 April 1973, another nonpregnant female was shot 3.2 km south-southwest of Jugornot. The latter animal may have been a late migrant that year due to record low temperatures in early April.

Eptesicus fuscus (Palisot de Beauvois), big brown bat.

During the summer months, I estimated the presence of more than a million big brown bats in nursery colonies in Somerset, but I have been unable to find this species in the same buildings during winter. In the winter of 1972–1973, only 5 male and 11 female big brown bats were found in Pulaski County caves that I examined. The winter disappearance of this species is not unique to Pulaski County since John Whitaker (pers. comm.) has reported the phenomenon in west-central Indiana.

The big brown bat begins to appear at its nursery colonies during the latter part of April, and the young usually are born the first week in June. By early July, the young are capable of fending for themselves. On an afternoon in early July 1972, more than 300 juveniles were found clinging to the side of a house at 124 Bourne Avenue, Somerset. Upon observing the phenomenon, I noticed that as the juveniles tried crawling to the entrances leading to the attic, they were promptly turned away by the adults. By the next morning, most exiled juveniles were gone.

There are several places in Somerset where *E. fuscus* is found inhabiting chimneys; I do not know, however, if this species coexists with the Chimney Swift (*Chaetura pelagica*).

A single female big brown bat shared a rafter with a colony of *P. rafinesquii* in the abandoned house 3.2 km west-southwest of Ingle.

Pipistrellus subflavus (F. Cuvier), eastern pipistrelle.

This probably is the most common bat in Pulaski County and is a very common hibernator in almost all caves. Between 17 October 1972 and 7 May 1973, I banded 154 pipistrelles as follows: Sloan's Valley Cave, 12 males, 11 females; unnamed cave, 2.8 km east-northeast of Somerset, 1 male, 1 female; unnamed cave beneath Buck Creek Bridge on State Hwy 192, 4 males, 4 females; unnamed cave 2.4 km northwest of Mount Victory, 3 males, 1 female; Dumplin Cave, 2 females; Hail's Cave, 73 males, 42 females. These sex ratios are in general agreement with those reported by Davis (1959).

During the winter 1972–1973, I observed that frequent movement took place within the population as some pipistrelles would leave a given cave to return at a later time. I found no movements between caves.

On 25 May 1973, I found only 1 banded pipistrelle in Sloan's Valley Cave, but 50 other pipistrelles (all males) without bands were also present. The summer distribution of the many banded pipistrelles has not been established.

I have shot pipistrelles on only a few occasions. A female was shot on 20 June 1972, 3.2 km south-southeast of Jugornot. She was pregnant with 2 embryos, 23 mm in crown–rump length. A male was shot at the same location on 6 September 1972. On 26 June 1972, a *P. subflavus* was observed fluttering like a moth around a mercury vapor lamp at a house 0.5 km east of Ruth. On 4 June 1973, at least 24 pipistrelles were seen fluttering above a mercury vapor lamp 1.6 km north of Somerset; a single male was shot.

On 22 February 1973, the carcass of a pipistrelle was found at the entrance of an unnamed cave beneath the Buck Creek Bridge on State Hwy 192. The carcass was on a rock ledge near the entrance of the cave with 2 owl pellets containing the remains of a *Microtus* nearby. I surmised that the bat probably was killed by an owl.

Several pipistrelles found hibernating in February 1971 were infested with 1 to 4 adult ticks.

Davis (1964) reported the swarming of pipistrelles at Dixon Cave, Kentucky. This phenomenon was observed 23 August 1972 at Sloan's Valley Cave. Several hundred bats swarmed at the entrance of the cave; the predominant species was *P. subflavus*.

Myotis leibii (Audubon and Bachman), least brown bat.

I have encountered the least brown bat twice in south-central Kentucky. The first occurrence was in Wayne County on 18 June 1973 at the Otter Creek Bridge on State Hwy 90. On 29 June 1973, I found 2 male *M. leibii* in expansion joints of the Rockcastle River Bridge on State Hwy 192. The bridge is on the boundary between Pulaski and Laurel counties.

Myotis sodalis (Miller and Allen), Indiana bat.

This species has been observed on occasion in Sloan's Valley Cave and Hail's Cave. Increasing disturbances by man may be a factor in the demise of the Indiana bat. On several occasions, I have entered Sloan's Valley Cave and found vandals throwing rocks at hibernating clusters of bats. At other times, the smoke from spelunker's fires has so completely filled several passages that hibernating bats have aroused and left the caves.

Myotis keenii (Merriam), Keen's bat.

This species is rather rare in Pulaski County. Specimens have been collected during March at an unnamed cave 5.6 km south of Hail, and during June and August at Sloan's Valley Cave. During the winter of 1972–1973, only 4 *M. keenii* were banded.

This species was most frequently encountered at Sloan's Valley Cave during the swarming activities in late summer. It ranked second after *P. subflavus* in numbers seen.

Myotis lucifugus (Le Conte), little brown bat.

One of our most common hibernators at Sloan's Valley Cave is the little brown bat; I have estimated the winter population in excess of 300 bats. During the winter 1972–1973, 142 male and 64 female little brown bats were banded. Upon checking Sloan's Valley Cave on 25 May 1973, only 8 little brown bats were observed; 4 exhibited bands, the others had left.

Only at Sloan's Valley Cave and Hail's Cave have large numbers of this species been found. The species begins to return to the caverns about mid-September. *M. lucifugus* has only rarely been taken or seen during June and July. The bridge crossing the Rockcastle River on State Hwy 192 is the most favored roost of summer resident little brown bats observed to date. No colonies of *M. lucifugus* have been found in attics of houses in Pulaski County, though I do know of such a situation in nearby Williamsburg, Whitley County.

Sylvilagus floridanus (J. A. Allen) eastern cottontail.

This rabbit is rather common and widespread throughout the entire county. During the summer of 1972, an eastern cottontail that became a "pet" at Somerset Community College was observed with 4 litters. The young were born in mid-March, early May, late June, and mid-August.

Marmota monax (Linnaeus), woodchuck.

The woodchuck is a very common resident in all parts of Pulaski County. Juvenile woodchucks taken on 9 April 1972 and 5 May 1973 were having their permanent premolars erupt though the deciduous premolars were still present.

Tamias striatus (Linnaeus), eastern chipmunk.

Both subspecies of chipmunks, *T. s. striatus* and *T. s. ohioensis*, are found in Pulaski County.

Sciurus carolinensis (Gmelin), gray squirrel.

The gray squirrel is a very common inhabitant of the hickory, oak, dogwood, maple, and walnut forests of Pulaski County.

Sciurus niger (E. Geoffroy St. Hilaire), fox squirrel.

The fox squirrel is rather infrequently encountered in Pulaski County. It is most likely to be observed in the woods surrounding Lake Cumberland or its tributaries.

There appears to be about equal frequency of color phases between red phase and gray phase as reported by Hall and Kelson (1959). A female shot near the Lincoln–Pulaski County line on 28 December 1972 was a mosaic individual of the red phase. She had a black facial wash, but her venter was completely melanistic. Her tail was a deep reddish-orange color. A mass of sperm in the vagina indicated that the squirrel had recently copulated.

Glaucomys volans (Linnaeus), southern flying squirrel.

The southern flying squirrel is a common resident inhabiting hollow snags, beech trees, attics, and birdhouses. A female found in a birdhouse 3.2 km east of Burnside on 14 May 1973 had 2 young, 172 and 165 mm in total length. The juveniles were capable of gliding on their own and ate limited quantities of beef liver. I suspect the young were about to be weaned.

Castor canadensis (Kuhl), beaver.

Beavers were natives of Pulaski County before their extermination by fur trappers. Today, a few beaver are found in the Beaver Creek drainage as the Fish and Game Commission tried to reestablish the animal in its former range.

Peromyscus leucopus (Rafinesque), white-footed mouse.

This species is the dominant species of *Peromyscus* in Pulaski County. I have taken it in all habitats, open fields, dense forests, along streams, and dense brush. A female captured on 13 February 1973 contained 4 embryos, 18 mm in crown–rump length. *P. leucopus* shows varying degrees of polymorphism within the population.

Neotoma floridana (Ord), eastern wood rat.

Wood rats are locally abundant in Pulaski County. I have collected specimens from 2.1 km southeast of Somerset. I have also seen *N. floridana* in Hail's Cave and in an abandoned house south of Burnside.

Microtus ochrogaster (Wagner), prairie vole.

The occurrence of the prairie vole in Pulaski County represents a slight range extension from that given by Hall and Kelson (1959). This species has been found at Mill Springs National Cemetery in Nancy, 1.6 km east of Science Hill, and 2.1 km southeast of Somerset. A female caught at Mill Springs National Cemetery on 29 April 1972 had 5 embryos, 3 were 10 mm in crown–rump length while 2 were being reabsorbed.

Microtus (*Pitymys*) *pinetorum* (Le Conte), pine vole.

Two subspecies of the pine vole occur in Kentucky with the type specimen of *M. p. carbonarius* being reported by Handley (1952) from Eubank. I have collected specimens of presumably *M. p. carbonarius* from 3 locations in Pulaski County.

Ondatra zibethicus (Linnaeus), muskrat.

The muskrat is a common inhabitant of the small rivers, streams, and ponds in Pulaski County. Even though the amount of fur trapping in recent years has diminished, several hundred muskrats are still caught by the few remaining professional trappers.

Synaptomys cooperi (Baird), southern bog lemming.

The range map of Hall and Kelson (1959) excludes the southern bog lemming from Pulaski County. Barbour (1956) described a new subspecies, *S. c. kentucki*, from north-central Kentucky, the nearest record occurring in Richmond, Madison County. *S. c. stonei* has its closest occurrence at Goldbug, Whitley County. I have collected 2 specimens of *S. cooperi* from 1.6 km east of Science Hill. A specimen collected on 5 November 1972 was a female containing 2 embryos, 10 mm in crown–rump length. The animals were found on a wooded knob with scattered areas of dense undergrowth.

Zapus hudsonicus (Zimmerman), meadow jumping mouse.

Wallace (1971) reported the presence of *Z. hudsonicus* from Lyon, Oldham, Daviess, and Madison counties.

In October 1971, a resident near Pitman Creek at Ruth reported seeing a mouse that jumped and had a long tail, but I was unable to obtain any by trapping. On 14 May 1973, I was presented a specimen of this species caught at Nelson Valley, 3.2 km north of Somerset on State Hwy 39. The area is a bottomland along Pitman Creek, 7.2 km by air northwest of Ruth. I suspect that additional jumping mice may be caught between Ruth and Nelson Valley along Pitman Creek.

Vulpes fulva (Desmarest), red fox.

The red fox is rather rare in Pulaski County. The few animals seen usually are present in the more heavily forested portions of the county.

Urocyon cinereoargenteus (Schreber), gray fox.

This species is very common throughout the country. The animals prefer to hunt in the open fields with nearby woods into which they can retreat. Several hundred of these mammals are killed yearly by automobiles in Pulaski County. This species frequently is a vector for rabies, and in adjacent Casey County, the rabies virus has eliminated a number of these animals. There have been no recent reports in Pulaski County of rabid gray foxes.

Procyon lotor (Linnaeus), raccoon.

The raccoon is frequently observed at night along the larger streams in the county. In the summer, raccoons frequently invade corn fields to feed on the young succulent ears of corn.

Mustela vison (Schreber), mink.

Local fur trappers encounter the mink along the several tributaries to Lake Cumberland, and even in swampy and marshy areas. Mink frequently are the casualty of automobiles on major highways. I have collected specimens from north of Somerset and south of Eubank and have also seen mink in the forest east of Mt. Victory.

Mephitis mephitis (Schreber), striped skunk.

This skunk lives in the flat open areas of Pulaski County. I collected a specimen from 1.6 km east of Somerset. I suspect that trophic competition between the striped skunk and the opossum may be a restricting factor in the abundance of the skunk.

Odocoileus virginiana (Zimmerman), white-tailed deer.

This species is hunted locally, with most kills occurring in southern Pulaski County. The number of animals present would be greatly enhanced if out-of-season hunting was reduced and if feral dog packs were eliminated. Certain parts of the county produce extensive browse conducive to the well-being of white-tailed deer.

MAMMALS OF QUESTIONABLE OCCURRENCE

The presence of 13 species of mammals in Pulaski County remains indefinite. I found no evidence to indicate the presence of *Sorex longirostris* (southeastern shrew), *Sylvilagus aquaticus* (swamp rabbit), *Oryzomys palustris* (marsh rice rat), *Reithrodontomys humulis* (eastern harvest mouse), *Peromyscus maniculatus* (deer mouse), *Peromyscus* (*Ochrotomys*) *nuttalli* (golden mouse), *Sigmodon hispidus* (hispid cotton rat), *Microtus pennsylvanicus* (meadow vole), and *Spilogale putorius* (eastern spotted skunk).

Myotis grisescens (gray bat) lives in nursery colonies in nearby Adair and Garrard counties. This bat prefers caves with a good flow of water, several of which occur in Pulaski County.

Ursus (*Euarctos*) *americanus* (black bear) was supposedly seen by several residents in the Stab community in 1971. However, a search for clues concerning the presence of a bear proved fruitless.

Mustela frenata (long-tailed weasel). In talking with local trappers, the last known weasel caught was 5 or 6 years ago. Local poultry specialists have not had recent reports of weasels raiding chicken houses.

LITERATURE CITED

BARBOUR, R. W. 1951. The mammals of Big Black Mountain, Harlan County, Kentucky. J. Mammal. 32:100–110.

———. 1956. *Synaptomys cooperi* in Kentucky, with description of a new subspecies. J. Mammal. 37:413–416.

———. 1957. Some additional mammal records from Kentucky. J. Mammal. 38:140–141.

———, AND W. H. DAVIS. 1969. Bats of America. University Press of Kentucky, Lexington, Ky. 286 pp.

DAVIS, W. H. 1959. Disproportionate sex ratios in hibernating bats. J. Mammal. 40:16–19.

———. 1964. Fall swarming of bats at Dixon Cave, Kentucky. Bull. Natl. Speleolog. Soc. 26:82–83.

———, AND W. Z. LIDICKER, JR. 1956. Winter range of the red bat, *Lasiurus borealis*. J. Mammal. 37:280–81.

FASSLER, D. J. 1971. A range extension of Rafinesque's big-earred bat in Kentucky. Bat Res. News 12:41.

———. 1972. An additional record of the hoary bat in Kentucky. Trans. Ky. Acad. Sci. 34:36.

———. 1973. An additional evening bat from south-central Kentucky. Trans. Ky. Acad. Sci. 34:46.

———. 1974. Red bat hibernating in a woodpecker hole. Amer. Midl. Nat. In press.

HALL, E. R., AND K. KELSON. 1959. The Mammals of North America. The Ronald Press Co., New York, N.Y. 2 vols.

HANDLEY, C. O., JR. 1952. A new pine mouse (*Pitymys pinetorum carbonarius*) from the southern Appalachian Mountains. J. Wash. Acad. Sci. 42:152–153.

LEWIS, R. Q., SR. 1974. Geologic map of the Somerset quadrangle, Pulaski County, Kentucky. U.S. Geol. Survey Geol. Quad. Map. G.Q. In press.

OOSTING, H. J. 1956. The study of plant communities. W. H. Freeman Co., San Francisco, Calif. 440 pp.

WALLACE, J. T. 1971. New records of *Zapus hudsonicus* (Zimmerman) from Kentucky. Trans. Ky. Acad. Sci. 32:65–69.

A Phytosociological Study of a Relict Hardwood Forest in Barren County, Kentucky

Christine K. Bougher and Joe E. Winstead
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Analysis of a hardwood forest at Bonayer in Barren County, Kentucky, revealed a mature forest system with high tree species diversity and an age in excess of 150 years. The forest may be characterized as an oak forest, primarily due to the importance of *Quercus alba* in the stand. Accessory species are *Nyssa sylvatica*, *Carya ovata*, *Liquidambar styraciflua*, and *Liriodendron tulipifera*. *Cornus florida* is prevalent in the understory. A high degree of similarity is evident between the tree composition and the younger growth in the forest indicating a relatively stable forest system. Comparison with second and third growth forest stands in the surrounding area reveals that the same species are dominant in the younger developing stands. This suggests that the Bonayer Forest represents the climax vegetation of the area. The mature forest shows a mean dbh of 7.0 inches (17.8 cm), density of 289 trees per acre (713 trees/ha), and a basal area of 138.5 square feet per acre (31.8 m^2/ha).

Introduction

Although general information is readily available concerning the structure and composition of deciduous forests, especially in the eastern part of the United States, there seems to be little specific information concerning forest composition in the Commonwealth of Kentucky. The lack of phytosociological studies prior to the development of the land, and the extent of land development of Kentucky, has led to the paucity of information regarding the natural forest vegetation of the Commonwealth. To the authors' knowledge, there are few publications dealing with the vegetational composition of relict or virgin forests in Kentucky. It is apparent that there is a special need for studies of natural areas that have been relatively undisturbed by man. A small wooded area in Barren County, Kentucky, referred to as Bonayer Forest, was chosen for a detailed phytosociological analysis in 1971 after a preliminary investigation indicated that the forest might be representative of the natural vegetation of south central Kentucky.

This study was undertaken to describe the vegetational composition of the forest, to gain some insight into the successional development of the stand, to compare the tree composition of the forest with that of representative woodlots in the surrounding area, and to establish a record of Bonayer Forest as a basis for possible future studies of a structural or functional nature. An underlying aim of this investigation was to determine whether or not this small forest is indicative of the vegetational composition that would be present in the region if it were undisturbed by man.

The study area consists of approximately 14.5 acres (5.9 hectares) of mature hardwood forest in Barren County, Kentucky, 25 miles (40.25 km) east of Bowling Green and 6 miles (9.7 km) west of Glasgow on U.S. Highway 68 at the village of Bonayer. This woods was part of a Revolutionary War Grant to the Read family of Glasgow. To the knowledge of the last 3 Read generations (approximately 125 years) there has been no timber removed except for dead chestnut trees after the epidemic of chestnut blight in the late 1930's. Prior to 1971, the forest covered some 30 acres (12.1 ha), but during that year, a part of the Cumberland Parkway was cut through the woods, leaving less than half of the former stand.

Barren County is within the eastern and western Pennyroyal physiographic regions of Kentucky, which are parts of the Mississippian plateau (McFarlan 1943). The plateau is underlain by sedimentary rocks primarily of Mississippian age, with Devonian rocks in some areas. The topography of the county is predominantly that of a dissected plateau, and varies greatly. Bonayer Forest is on a nearly level section of land within an area of gently rolling topography.

According to a soil survey of Barren County (Latham 1969), the soils underlying Bonayer Forest have been classified as Dowellton and Taft silt loams. Both are nearly level, poorly drained, acid soils on upland flats. These soils were developed in residual or alluvial material derived chiefly from limestone and partly from sandstone or shale. The natural fertility of Dowellton and Taft silt loams is moderately low; organic matter is low.

The area now known as Barren County was settled following an order of the Virginia Convention in 1789, which declared that all the lands between the Barren and Green rivers would be given to soldiers of the Continental Army. Barren County was formed from Warren and Green counties in 1789 and originally included all of Metcalfe County, large parts of Hart and Monroe counties, and a part of Allen County. The name of Barren County was derived from the term "barrens" given by the early settlers to a treeless grassland roughly corresponding to the area of karst topography in central Kentucky. According to Shaler (1884) the early settlers considered these lands to be worthless and unproductive since they did not support the magnificent forests expected of fertile land. The lack of trees may have been due to periodic fires set by the Indians to burn off old grass, thus providing better forage for buffalo and other large game. When the Indians no longer made regular hunting expeditions into Kentucky (about 1790), the grassland known as the Barrens was quickly restored (Shaler 1884).

It is impossible to determine whether the present study site was a part of what was then the Barrens, or if it was part of the originally forested region which surrounded the Barrens. Franklin Gorin (1876), commenting on the appearance of Barren County in 1798, said:

> "The country north, northwest, and northeast of Glasgow was mostly barrens, poorly watered and lightly timbered, but the rest of the country . . . was heavily timbered with oak, black and white walnut, ash, sugar maple, hackberry, cherry, poplar, chestnut, beech, buckeye, etc."

Bonayer Forest is west and slightly north of Glasgow, so it would have been near the borderline between the wooded and barren regions as presented by Gorin. However, even if the study site was within the Barrens, it may have been reforested following 1790 (Shaler 1884, Hussey 1876). The history of Barren County, then indicates that the study site may have been covered with forest vegetation for 180 or more years.

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MATERIALS AND METHODS

The quadrat method (Oosting 1956) was used to determine species composition, relative density, and relative frequency of all size classes of vegetation as well as relative dominance (based on basal area) of tree species. At Bonayer, 23 quadrats of 10 m × 10 m dimensions were placed on 4 transect lines with a 30-m interval between each quadrat. Seven additional 100-m^2 quadrats were placed at random in the remaining area. The diameter

breast height (dbh) of each tree species greater than 2 inches (5 cm) dbh was recorded for each 100-m^2 quadrat. Saplings and shrubs less than 5 cm dbh and greater than 1 foot (30 cm) in height were sampled in 2 20-m^2 quadrats (2 × 10m) placed within each 100-m^2 quadrat. Seedlings less than 30 cm in height were counted and identified to genus in 4 1-m^2 (1 × 1 m) quadrats placed within each corner of the 100-m^2 quadrats.

In order to determine whether or not Bonayer Forest was different in tree composition than other forest stands in the locality, tree species were also sampled outside the Bonayer Forest. However, since no one forest of sufficient size for comparative purposes was found, we chose 6 wooded sites of similar topography and within a 5-km radius of the Bonayer Forest. All of those stands had obviously been disturbed and appeared to consist of second or third growth woods. This composite of 6 sites, referred to as the Surrounding Area, was sampled by 20 quadrats randomly placed among the 6 sites. Within each of the 10-m × 10-m quadrats, species greater than 5 cm dbh were recorded.

To check the adequacy of sampling at Bonayer, species–area curves were determined for trees, saplings and shrubs, and seedlings (Oosting 1956). Sampling was considered adequate when a 10 percent increase in area sampled yielded additional species equal to only 5 percent of the total present. This point indicated the minimum number of quadrats which should be used to obtain a representative sample of the vegetation.

Tree data were analyzed to provide mean diameter at breast height, mean density per hectare, and mean basal area per hectare of Bonayer Forest and of the Surrounding Area. Relative density, relative frequency, and relative dominance were calculated and summed to give importance values for each tree species (Curtis and McIntosh 1951). Relative density plus relative frequency values were determined for saplings, shrubs, and seedlings.

Collections were made of all tree and shrub species found in the study area. Specimens have been deposited in the Herbarium of Western Kentucky University. Plant nomenclature follows that of Gleason and Cronquist (1963).

To determine the approximate height of the canopy in the Bonayer stand, several random tree height measurements were taken using an Abney level.

When the State Department of Highways cut through a section of the woods in 1971, stumps provided a record of annual growth rings. A random sample of the cutover area was made and 18 tree stumps were analyzed to give an approximation of the age of the stand.

A soil sample of the first 8 cm of soil was obtained from the center of each 100-m^2 quadrat in the Bonayer woods. A LaMotte Soil Test Kit was used to measure soil pH. Soil texture was analyzed by the hydrometer method of Bouyoucos (1936).

To gain some insight into the total productivity of the forest stand, falling leaves, stems, and fruits were collected from October through February. Nearly all annual litter fall was expected during that period. At the midpoint of each transect line, a 0.5-m square box with a wire mesh bottom was placed to catch falling debris. Litter was periodically removed from the boxes, dried in a drying oven, and weighed to the nearest 0.1 g.

Diversity values for trees in both Bonayer Forest and the Surrounding Area were calculated using the Shannonn–Weaver diversity formula (Wilhm and Dorris 1968) which was programmed into a PDP8 computer. For the Bonayer Forest data, 3 groups of 20 randomly chosen 100-m^2 quadrats were analyzed and the mean of these 3 diversity values was then comparable to that based on the 20 quadrats in the Surrounding Area. Another expression of diversity is the slope (b) of the regression $\log Y = bx$ where Y is the number of individuals and x is the number of species (Williams 1964). The

TABLE 1.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF TREES OVER 2 INCHES (5 CM) DBH IN BONAYER FOREST

Species	N	RD	RF	RDo[1]	IV
Quercus alba	24	11.2	11.2	38.9	61.3
Nyssa sylvatica	27	12.6	9.8	6.7	29.1
Carya ovata	24	11.2	10.5	5.1	26.8
Liquidambar styraciflua	18	8.4	8.4	5.3	22.1
Liriodendron tulipifera	9	4.2	6.3	9.8	20.3
Cornus florida	18	8.4	7.7	1.1	17.2
Fagus grandifolia	8	3.7	5.6	7.7	17.0
Sassafras albidum	15	7.0	4.9	1.5	13.4
Carpinus caroliniana	13	6.1	6.3	.6	13.0
Quercus velutina	8	3.7	3.5	5.4	12.6
Acer rubrum	8	3.7	4.2	4.2	12.1
Carya tomentosa	8	3.7	3.5	1.0	8.2
Ulmus alata	6	2.8	3.5	1.3	7.6
Acer saccharum	6	2.8	2.8	.8	6.4
Carya glabra	5	2.3	2.1	2.0	6.4
Quercus spp.	1	.5	.7	5.1	6.3
Fraxinus americana	4	1.9	2.1	.4	4.4
Fraxinus nigra	4	1.9	1.4	.7	4.0
Quercus coccinea	2	.9	1.4	1.0	3.3
Prunus serotina	2	.9	1.4	.4	2.7
Ulmus rubra	1	.5	.7	1.0	2.2
Fraxinus pennsylvanica	1	.5	.7	.1	1.3
Amelanchier arborea	1	.5	.7	.0	1.2
Oxydendrum arboreum	1	.5	.7	.0	1.2

[1] Basal area equals 138.5 ft², 12.9 m².

regression coefficient or slope (b) was determined for trees in Bonayer Forest.

RESULTS

Species–area curves for trees, saplings and shrubs, and seedlings demonstrated that, in all cases, samples were more than adequate for analysis of the vegetational composition of the forest. A minimum number of 18 of the 100-m² quadrats was necessary to characterize the tree species present at Bonayer Forest; an additional 12 quadrats were used. Saplings and shrubs were sampled in 60 of the 20-m² quadrats whereas 24 quadrats would have been sufficient. The 120 1-m² quadrats used to sample seedlings were in excess of the minimum number of 52 quadrats for this stratum of vegetation. A species–area curve for trees in the Surrounding Area showed that the minimum number of 100-m² quadrats needed was 12, so the 20 quadrats placed in the Surrounding Area also constituted an adequate sample for analysis.

TABLE 2.—DIAMETERS (IN CENTIMETERS) OF THE 10 MOST COMMON TREE SPECIES IN BONAYER FOREST, SHOWING THE NUMBER OF TREES IN EACH CLASS, BASED ON 214 TREES

	5.0–12.6	12.7–27.7	27.8–42.9	43.0–58.2	58.3+
Quercus alba	2	8	3	6	5
Carya ovata	15	7	2		
Nyssa sylvatica	17	7	3		
Liquidambar styraciflua	12	3	2	1	
Cornus florida	18				
Liriodendron tulipifera	1	4	3		1
Fagus grandifolia	4	2			1
Carpinus caroliniana	13			1	
Sassafras albidum	12	3			
Acer rubrum	5	2			1

In the Bonayer Forest, 24 tree species are included in the sample of 30 quadrats. When tree species at the Bonayer Forest are ranked according to importance values (Table 1), the 4 most predominant species (and their importance values) are *Quercus alba* (61.3), *Nyssa sylvatica* (29.1), *Carya ovata* (26.8), and *Liquidambar styraciflua* (22.1). *Q. alba* has a much greater relative dominance (38.9) than any other tree species. *Cornus florida* is the most abundant understory tree with a relative density of 8.4.

The total of 214 trees recorded at Bonayer Forest correspond to a density of 713 per hectare. The trees have a mean dbh of 17.8 cm, and a total basal area of 31.8 m² per hectare. Diameter size class distribution of the 10 most common tree species in the Bonayer Forest (Table 2) shows a generally even distribution of trees over several size classes. *Quercus alba* is present in all 5 size classes and is the only species so evenly distributed. *Liquidambar styraciflua*, *Liriodendron tulipifera*, and *Fagus grandifolia* are each distributed over 4 different size classes. Only 2 species, *Cornus florida* and *Carpinus caroliniana* are restricted to the smallest size group of 5–12.5 cm dbh. In these data, 8 individuals of 4 different species show dbh's of 23.0 inches (58.4 cm) or greater.

TABLE 3.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), AND RELATIVE DENSITY PLUS RELATIVE FREQUENCY (RD&RF) VALUES FOR SAPLINGS AND SHRUBS IN BONAYER FOREST. DATA GATHERED FROM 60 2 × 10-M QUADRATS

Species	N	RD	RF	RD&RF
Saplings				
Cornus florida	142	4.3	7.1	11.4
Carpinus caroliniana	128	3.9	6.2	10.1
Fraxinus spp.	108	3.3	6.7	10.0
Acer spp.	67	2.0	6.2	8.2
Nyssa sylvatica	90	2.7	5.4	8.1
Carya spp.	62	1.9	6.0	7.9
Sassafras albidum	66	2.0	5.1	7.1
Liquidambar styraciflua	58	1.8	4.2	6.0
Prunus serotina	34	1.0	3.8	4.8
Fagus grandifolia	30	.9	3.6	4.5
Quercus velutina	28	.8	3.3	4.1
Liriodendron tulipifera	45	1.4	2.5	3.9
Quercus alba	31	.9	2.7	3.6
Ulmus spp.	17	.5	2.0	2.5
Castanea dentata	7	.2	1.3	1.5
Morus rubra	6	.2	.7	.9
Juniperus virginiana	2	.1	.4	.5
Cercis canadensis	1	.0	.2	.2
Ostrya virginiana	1	.0	.2	.2
Shrubs				
Euonymus americanus	1883	57.2	10.7	67.9
Smilax spp.	218	6.6	7.8	14.4
Corylus americana	83	2.5	3.6	6.1
Lindera benzion	56	1.7	3.8	5.5
Asimina triloba	68	2.1	1.6	3.7
Aralia spinosa	36	1.1	1.8	2.9
Vaccinium stamineum	10	.3	1.1	1.4
Vitis spp.	6	.2	.5	.7
Amelanchier arborea	5	.2	.5	.7
Rhamnus carolinianus	1	.0	.2	.2
Lonicera japonica			.9	

TABLE 4.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), AND RELATIVE DENSITY PLUS RELATIVE FREQUENCY (RD&RF) VALUES FOR TREE AND SHRUB SEEDLINGS IN BONAYER FOREST. DATA GATHERED FROM 120 SQUARE METER QUADRATS

Species	N	RD	RF	RD&RF
Tree Seedlings				
Quercus spp.	238	28.9	14.1	43.0
Acer spp.	105	12.8	13.1	25.9
Liquidambar styraciflua	103	12.5	11.3	23.8
Liriodendron tulipifera	73	8.9	8.6	17.5
Nyssa sylvatica	31	3.8	6.0	9.8
Carya spp.	29	3.5	6.0	9.5
Carpinus caroliniana	30	3.6	5.3	8.9
Sassafras albidum	30	3.6	4.8	8.4
Fraxinus spp.	28	3.4	4.5	7.9
Cornus florida	26	3.2	4.0	7.2
Ulmus spp.	15	1.8	3.5	5.3
Prunus serotina	14	1.7	2.8	4.5
Amelanchier spp.	2	.2	.5	.7
Morus rubra	2	.2	.2	.4
Fagus grandifolia	1	.1	.2	.3
Unknown seedlings	6	.7	1.0	1.7
Shrub Seedlings				
Smilax sp.	43	5.2	7.0	12.2
Lindera benzion	27	3.3	5.3	8.6
Corylus americana	10	1.2	.5	1.7
Aralia spinosa	8	1.0	.5	1.5
Vaccinium stamineum	2	.2	.5	.7

When saplings and shrubs are ranked according to relative density plus relative frequency values, 3 genera appear as important understory trees in Bonayer Forest (Table 3). These are *Cornus florida* (11.4), *Carpinus caroliniana* (10.1), and *Fraxinus* spp. (10.0). *Euonymus americanus* is by far the most important shrub in the woods due to its high density of 6,357 individuals per acre (15,701/ha) and its frequency of 98.3 percent. Other common shrubs are *Smilax* sp., *Corylus americana*, *Lindera benzion*, and *Asimina triloba*. It is interesting to note that a few *Castanea dentata* root sprouts are present in the woods.

Relative density plus relative frequency values for seedlings in Bonayer Forest (Table 4) show that *Quercus* spp. (43.0), *Acer* spp. (25.9), and *Liquidambar styraciflua* (23.8) are the most dominant tree seedlings, while *Smilax* sp. (12.2) and *Lindera benzion* (8.6) are the most common shrub seedlings.

Woody vines present at Bonayer Forest and their frequencies in the seedling stratum are *Parthenocissus quinquefolia* (36.7), *Lonicera japonica* (10.8), *Rhus radicans* (10.8), and *Vitis* spp. (3.3). Herbaceous plants noted in the Bonayer woods are *Aralia racemosa*, *Ariseama triphyllum*, *Athyrium thelyteroides*, *Boehmeria cylindrica*, *Chimaphila maculata*, *Commelina communis*, *Desmodium* sp., *Houstonia* sp., *Impatiens biflora*, *Mitchella repens*, *Onoclea sensibilus*, *Osmunda regalis*, *Panicum*

TABLE 5.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF TREES OVER 5 CM DBH IN THE SURROUNDING AREA

Species	N	RD	RF	RDo[1]	IV
Liriodendron tulipifera	32	15.6	8.9	24.4	48.9
Cornus florida	44	21.5	14.8	7.1	43.4
Quercus velutina	16	7.8	8.9	17.8	34.5
Nyssa sylvatica	20	9.8	9.9	9.9	29.6
Acer rubrum	14	6.8	7.9	9.3	24.0
Liquidambar styraciflua	13	6.3	6.9	5.1	18.3
Carya ovata	11	5.4	8.9	1.2	15.5
Quercus alba	9	4.4	4.0	3.0	11.4
Sassafras albidum	10	4.9	4.0	2.4	11.3
Prunus serotina	8	3.9	5.9	.9	10.7
Quercus borealis	3	1.5	2.0	6.4	9.9
Carya tomentosa	4	2.0	3.0	4.4	9.4
Carya glabra	3	1.5	2.0	3.9	7.4
Fagus grandifolia	6	2.9	2.0	.8	5.7
Carpinus caroliniana	4	2.0	3.0	.6	5.6
Juglans cinerea	1	.5	1.0	2.2	3.7
Cercis canadensis	2	1.0	2.0	.3	3.3
Fraxinus americana	1	.5	1.0	.1	1.6
Ulmus alata	1	.5	1.0	.1	1.6
Acer saccharum	1	.5	1.0	.0	1.5
Morus rubra	1	.5	1.0	.0	1.5
Rhamnus carolinianus	1	.5	1.0	.0	1.5

[1] Basal area equals 11.85 m^2.

sp., *Podophyllum peltatum*, *Polystichum acrostichoides*, *Sanicula canadensis*, *Smilacina racemosa*, *Thelypteris hexagonoptera*, and *Uvularia perfoliata*.

Tree data from 6 stands in the vicinity of Bonayer Forest (Table 5) give the total of 22 species which are included in the sample of the Surrounding Area. Of these, 17 species are common to both Bonayer Forest and the Surrounding Area. Surprisingly, *Cornus florida*, an understory tree, has the second highest importance value (43.4) in the Surrounding Area. This is due to its high relative density (21.5) and frequency (14.8) within the stands. The most important overstory trees in the Surrounding Area are *Liriodendron tulipifera* (48.9), *Quercus velutina* (34.5), *Nyssa sylvatica* (29.6) and *Acer rubrum* (24.0). *Liriodendron tulipifera* has the greatest relative dominance (24.4) of any species in the Surrounding Area. In comparing the 4 most important overstory species in the 2 forest areas only *Nyssa sylvatica* is among the most important canopy species in both Bonayer Forest and the Surrounding Area.

TABLE 6.—DIAMETERS (IN CENTIMETERS) OF THE 10 MOST COMMON TREE SPECIES IN THE SURROUNDING AREA SHOWING THE NUMBER OF TREES IN EACH CLASS. DATA BASED ON 205 TREES

Species	5.0–12.6	12.7–27.7	27.8–42.9	43.0–58.2
Cornus florida	32	13		
Lirodendron tulipifera	12	12	6	2
Quercus velutina	7	3	2	4
Nyssa sylvatica	7	9	4	
Acer rubrum	8	4		2
Carya ovata	10	1		
Liquidambar styraciflua	6	5	2	
Prunus serotina	8			
Quercus alba	7	1	1	
Sassafras albidum	5	5		

For the Surrounding Area, 205 individuals with a mean dbh of 15 cm are included in the sample quadrats. These figures give a density of 1,025 stems per hectare and a total basal area of 11.9 m^2 for trees in the Surrounding Area. Diameter class distribution of the 10 most common tree species in the Surrounding Area (Table 6) shows a less even distribution over the various size classes than did the data from Bonayer Forest. No trees are present in the 58.4 cm or greater classification, and only 2 species, *Liriodendron tulipifera* and *Quercus velutina* are represented in 4 different size classes. *Cornus florida* is represented by 44 individuals, but they are restricted to the 2 smallest size classes, 5–12.5 and 12.5–27.7 cm dbh.

Both forest areas show high Shannonn–Weaver diversity values for tree species. A value of 3.685 was computed for the Surrounding Area; a diversity of 4.057 was found for the Bonayer Forest. Linear regression analysis of tree species data from Bonayer Forest yielded a regression coefficient of slope (b) of 0.0759, which is another measure of diversity. When used in this manner, the smaller the slope the greater the diversity or the more species encountered per given number of individuals.

TABLE 7.—GROWTH RING ANALYSIS OF 18 WHITE OAK STUMPS

Diameter (cm)	Number of Rings
26.7	69
30.5	80
34.3	71
36.8	63
39.4	147
43.2	108
50.8	163
54.6	158
61.0	81
71.2 (double trunk)	84
72.4	132
73.7	136
76.2	184
78.7	156
88.9	139
99.1	172
104.2	181
116.9	207

The diameter and number of annual rings counted for 18 *Quercus alba* cut from Bonayer Forest during highway construction (Table 7) indicate a great variation in the number of rings counted for similar sized trees, but provided information as to the age of the trees. Of the 18 white oaks cut during highway construction, 8 had stump widths ranging from 50 to 79 cm and showed from 81 to 184 years of growth. The largest stump analyzed was 116.8 cm in diameter with 207 annual rings.

Among the 24 white oaks that fell within the 10- × 10-m quadrats, the range of dbh was 5.3–79.2 cm. Of these, 8 (33%) were of the size class 5.3–24.0 cm; 8 (33%) measured 25.7–47.8 cm; 7 (29%) showed dbh's of 52.8–71.1 cm; and 1 white oak measured 79.2 cm. A few large white oaks measured outside the quadrats gave dbh's of 83.8, 74.9, 67.3, 62.2, and 49.0 cm.

Eleven random tree height measurements gave an average of 28.5 m for an approximation of canopy height. The dbh was recorded for 7 of the trees, but not for the remaining 4. The species, dbh, and height of the 7 trees were: 1 *Fagus grandifolia* dbh of 39.8 cm and a height of 22.7 m, 2 *Liquidambar styraciflua* with dbh's of 53.3 and 59.2 cm corresponding to heights of 24.8 and 24.2 m, 2 *Liriodendron tulipifera* with dbh's of 37.8 and 35.6 cm corresponding to heights of 28.5 and 26.5 m, and 2 *Quercus alba* with dbh's of 71.1 and 78.7 corresponding to heights of 36.6 and 26.4 m. The 3 remaining *Liriodendron tulipifera* had heights of 29.9, 30.8, and 31.7 m. One *Quercus alba* measured 30.8 m in height.

The productivity of Bonayer Forest, as determined by collection of litter, seemed to be low, with very little organic matter being added to the forest floor annually. Collections from the 4 litter boxes averaged 251 g of leaves, stems, and fruits per square meter of forest floor. Of that total, leaf litter accounted for 229 g; stems, 15 g; and fruit material, 8 g.

Soil analysis of 30 soil samples gave a range of pH from 4.5 to 5.8 with a mean of 5.1. The average sand, silt, and clay content of the first 8 cm of soil was 11.3, 59.8, and 28.9 percent, respectively. The majority of the soil samples (22) fell within the silty clay loam texture class, 7 samples were classified as silt loam, and 1 sample was sandy clay loam (Foth and Jacobs 1964). There are no apparent differences in vegetation which may be correlated with differences in soil texture or soil pH within the Bonayer stand.

DISCUSSION AND CONCLUSIONS

Data in Table 1 indicate that Bonayer Forest may be characterized as an oak forest, primarily due to the importance of *Quercus alba* in the stand. *Q. alba* has the second highest density as well as the highest frequency and dominance of any species there. Other oaks included in data from the Bonayer Forest are *Q. velutina*, *Q. coccinea*, and an individual of an unidentified species. Together, the oaks have an importance value of 81.9 which makes up 27.3 percent of the total importance value (300) for all species. Accessory species which follow oak in importance in the Bonayer Forest stand are *Nyssa sylvatica*, *Carya ovata*, *Liquidambar sty-*

TABLE 8.—COMPARISON OF THE 6 MOST IMPORTANT TREE, SAPLING, AND SEEDLING GENERA IN BONAYER FOREST

Trees		Saplings		Seedlings	
Genus	IV	Genus	RD&RF	Genus	RD&RF
Quercus	83.5	*Acer*	8.2	*Quercus*	43.0
Carya	31.4	*Nyssa*	8.1	*Acer*	25.9
Nyssa	29.1	*Carya*	7.9	*Liquidambar*	23.8
Liquidambar	22.1	*Quercus*	7.7	*Liriodendron*	17.5
Liriodendron	20.3	*Liquidambar*	6.0	*Nyssa*	9.8
Acer	18.5	*Prunus*	4.8	*Carya*	9.5

raciflua, and *Liriodendron tulipifera*. The understory of the Bonayer Forest is characterized by the presence of *Cornus florida*.

Diameter size class distribution of the 10 most common tree species in the Bonayer Forest (Table 2) indicated that reproduction is taking place since canopy species are also present in the smaller size classes. The generally even distribution of trees over several size classes is evidence that the forest has not been disturbed in the recent past. *Cornus florida* and *Carpinus caroliniana* are both restricted to only the smallest size class, but this is to be expected, since they are typical understory species.

When overstory tree species present in in each size class (tree, saplings, seedlings) are grouped into their respective genera and subsequently compared, a high degree of similarity is evident between the composition of the canopy and the younger growth in Bonayer Forest (Table 8). Genera which are typically restricted to the understory (*Cornus*, *Carpinus*, *Fraxinus*, and *Sassafras*) and would not be expected to replace dead or dying canopy trees have been omitted from these data. The 6 most important genera in the canopy of Bonayer Forest are *Quercus*, *Carya*, *Nyssa*, *Liquidambar*, *Liriodendron*, and *Acer*. Of these genera, 5 are present in this relative position in the sapling layer, and all 6 are present in the seedling layer. In the sapling stratum, *Liriodendron* is not among the 6 most important genera since both *Prunus* and *Fagus* have higher relative density plus relative frequency values (Table 5). It is not unusual for *Liriodendron* to be less important in the sapling stage than in the canopy because it is shade intolerant and does not survive well under a closed canopy. The relative importance of the different genera is not the same throughout the seedling, sapling, and tree stages, but many factors affect the numbers, growth, and survival of seedlings so that the relative importance of different genera often changes over time. Nevertheless, it is obvious from an examination of the seedling and sapling composition at Bonayer Forest that the same genera are present in these younger stages as in the canopy, indicating that the tree composition of Bonayer Forest probably will be much the same in the future.

Euonymus americanus (strawberry bush) has a greater relative density plus relative frequency value (67.9) than any other sapling or shrub in Bonayer Forest (Table 5). Its unexpected density of 6,357 individuals per acre (15,701/ha) and frequency of 98.3 percent cannot be explained by reference to the literature, since little research has been published on this species. *Euonymus americanus* deserves further study to determine the reason for its great abundance in Bonayer Forest.

Tree data from the Surrounding Area (Table 5) show both similarities and differences in composition when compared to that of Bonayer Forest. In the Surrounding Area, *Liriodendron tulipifera* and *Quercus velutina* are the most dominant tree species in contrast to Bonayer Forest, where *Quercus alba* is the most dominant. When all the oaks in the data of the Surrounding Area (*Q. velutina*, *Q. alba*, and *Q. borealis*) are grouped, their collective relative domi-

TABLE 9.—COMPARISON OF THE IMPORTANCE VALUES OF THE 7 MOST IMPORTANT TREE GENERA IN THE BONAYER FOREST AND THE SURROUNDING AREA

Bonayer Forest		Surrounding Area	
Genus	IV	Genus	IV
Quercus	83.5	*Quercus*	55.8
Carya	31.4	*Liriodendron*	48.9
Nyssa	29.1	*Cornus*	43.4
Liquidambar	22.1	*Carya*	32.3
Liriodendron	20.3	*Nyssa*	29.6
Acer	28.5	*Acer*	25.5
Cornus	17.2	*Liquidambar*	18.3

nance value (27.2) and importance value (55.8) are higher than those of *Liriodendron*. The Surrounding Area, then, may be characterized as oak–tulip poplar with *Cornus florida*, *Nyssa sylvatica*, *Acer rubrum*, *Liquidambar styraciflua*, *and Carya ovata* as accessory species. It is apparent that oaks are dominant in both Bonayer Forest and the Surrounding Area; *Nyssa sylvatica*, *Liquidambar styraciflua*, and *Carya ovata* are accessory species common to both. Comparison of the 7 most important genera in the Bonayer Forest and the Surrounding Area (Table 9) shows that the same 7 genera (*Quercus*, *Carya*, *Nyssa*, *Liquidambar*, *Liriodendron*, *Acer*, *Cornus*) are the most important in both areas. This similarity in fundamental composition is to be expected of 2 forest areas in the same locality.

Two primary differences in composition between Bonayer Forest and the Surrounding Area seem to indicate that Bonayer Forest is a more mature and less disturbed forest stand than any stand in the Surrounding Area. One difference is that the importance values of *Quercus alba* and *Q. velutina* are approximately reversed in the 2 areas. In the Bonayer Forest data, *Q. alba* has an importance value of 61.3 and *Q. velutina* one of 12.6; in the Surrounding Area *Q. alba* has an importance value of 11.4 *Q. velutina* one of 34.5 (Tables 1, 2). A second difference between the areas is that *Liriodendron* is much more predominant in the Surrounding Area than in the Bonayer Forest. Among the 7 most important genera in the Bonayer Forest data, *Liriodendron* ranks fifth with an importance value of 20.3; in the data of the Surrounding Area, *Liriodendron* approached *Quercus* in status with an importance of 48.9 (Table 10). Both these differences probably are the result of selective cutting in the Surrounding Area, removing the larger *Q. alba*, and opening up the canopy so that shade intolerant *Liriodendron* and *Q. velutina* have become more prominent. Bonayer Forest shows no indication of previous disturbance by cutting. The composition of the Surrounding Area, in the absence of further disturbance, probably will approach that of the Bonayer Forest in time.

Distribution of diameter size classes for the 10 most common trees in the Surrounding Area provides further evidence that the stands in the Surrounding Area are younger and more disturbed than those in the Bonayer Forest (Table 6). This is obvious since no trees in the 58.4 cm or greater size class were present as in the data from Bonayer Forest (Table 2). The Surrounding Area shows a less even distribution of trees over the various size classes. In the Bonayer Forest sample, *Quercus alba* was represented in all 5 size classes, but it was present in only the first 3 classes in the sample of the Surrounding Area. This suggests that the larger *Q. alba* have been cut out of the Surrounding Area.

Growth ring analysis of *Quercus alba* trees cut during highway construction gives an estimation of the age of Bonayer Forest. From 81 to 184 annual growth rings were counted for 8 white oak stumps with dbh's of 50–80 cm. One-third of the white oaks included in the sample data showed dbh's within this same range, implying an equal age for these living trees. It follows, then, that Bonayer Forest has been in existence for more than 150 years.

According to ecological theory, quality, larger size, high diversity, and stability are typical of mature systems, while the

opposite characteristics, quantity, small individuals, low diversity, greater production are typical of young systems. Comparison of trees from the Surrounding Area, from Bonayer Forest, and from a virgin forest in Indiana support the statement that numbers of individuals decrease and size of individuals increase as a system matures. Lindsey et al. (1958) found that in an impressive virgin forest called Donaldson's Woods, some trees reached up to 132 cm (52 inches) in dbh, the mean dbh was 29 cm (11.4 inches) there were 294 stems per hectare, and there was a basal area of 28.7 m^2/ha. Going from younger to more mature, the Surrounding Area, Bonayer Forest, and Donaldson's Woods show increasing mean dbh's of 15.2, 17.8, and 29.0 cm (6.0, 7.0, and 11.4 inches), respectively. Similarly, the 3 forest areas exhibit decreasing numbers of individuals, of 1,025, 713, and 294 stems per hectare (415, 289, and 123 stems per acre), respectively. It seems that basal area of a stand is not necessarily correlated with maturity since the basal area of the Surrounding Area of 29.4 m^2/ha is almost identical to that of Donaldson's Woods, while the basal area of Bonayer Forest is greater than either being 31.9 m^2/ha. This comparison of the 3 forest areas suggest that although Bonayer Forest is more mature than the Surrounding Area, it does not exhibit a mean dbh and density which are characteristic of a virgin forest.

In general, high species diversity is considered characteristic of mature systems. According to Shannonn–Weaver diversity index, Bonayer Forest shows a slightly higher tree species diversity (4.057) than does the Surrounding Area (3.685). Since an almost equal number of species was present in both samples, the lower diversity value for the Surrounding Area is due primarily to less evenness in the apportionment of individuals among the species. Linear regression analysis of species data from the Bonayer Forest gave a slope (b) of 0.0759, where lower slope values signify higher diversity. Monk and McGinnis (1966), in a study of forest community types in Florida, found that known successional communities such as sandhills, cypress heads, and flatwoods gave slopes ranging from 0.1275 to 0.2262, while known climax communities such as the southern mixed hardwoods gave slopes of 0.0554 to 0.1160. The slope of 0.0759 calculated for the Bonayer Forest falls within the range of slopes which Monk and McGinnis found characteristic of known climax types. This indicates that Bonayer Forest has a high diversity typical of climax communities.

The small amount of litter deposited on the forest floor could be used to support the idea that the Bonayer Forest is a stand that has neared homeostasis. Although the litter samples were limited in number, the amount collected in the litter traps seemed consistent with the appearance of litter on the forest floor. The value of 251 g/m^2 of litter in 1972–1973 is much less than the 600 g/m^2 of litter deposition obtained by Bray and Gorham (1964) for warm temperate forests between 34 and 38 degrees North latitude. This is evidence that the Bonayer Forest has low productivity, or that the community energetics are such that the gross production to biomass ratio (P/B ratio) is low. A low P/B ratio is typical of a mature system, one which is approaching homeostasis.

A species list compiled by Hussey (1876) from collections in the western part of Barren County, in the cave region, and in Edmonson County contains all of the tree species present in the Bonayer Forest data, as well as 22 of 32 different species of genera of shrubs, woody vines, and herbs. Hussey stated that on the more level parts of Barren County, trees were still small in size and few in species, which he felt was evidence of the recent introduction of forest growth into the region. He noted that the largest trees in this section of Barren County were oaks 15 inches (38 cm) in diameter. This may be contrasted to white oaks which attained enormous development along the Green River, forming "immense trunks, reaching to a height

of eighty feet, where they still seem to be three feet in diameter." Most of the species present in the Bonayer Forest, then, are identical to those found in the region nearly 100 years ago. The difference in size between trees in Barren County and elsewhere at that time may explain why trees in the Bonayer Forest do not approach the tremendous size expected of a virgin forest.

Bonayer Forest is included within the Mississippian Plateau of the Western Mesophytic Forest Region by Braun (1964), which she designated as a transition region characterized by a "mosaic pattern of climax vegetation types" rather than a single climax type. Braun indicated the dominance of oak forest over much of the Mississippian Plateau. Accessory species which vary from place to place may include sugar maple, beech, tulip tree, chestnut, hickories, white ash, and occasional other species. In sampling the canopy trees at one location in Barren County, Braun found that oaks formed half of the canopy with maple and beech the next most frequent. If all trees greater than 30 cm dbh in the Bonayer Forest data are considered, oaks form 51.5 per cent of the canopy with tulip tree as the next most frequent. The designation of Bonayer Forest as an oak forest is therefore consistent with generalizations and specific data presented by Braun.

This study has provided evidence that Bonayer Forest is typical of what the vegetational composition would be in south central Kentucky if this area were left undisturbed by man. The composition of the forest is oak, with black gum, shagbark hickory, sweetgum, and tulip poplar as accessory species. Bonayer Forest is similar in composition to stands in the Surrounding Area, but is a more mature forest system. The same genera of trees are present in the younger growth stages as are present in the canopy, indicating that the canopy trees are replacing themselves and that the Bonayer Forest represents a climax vegetation type.

Literature Cited

Bouyoucos, G. J. 1936. Directions for making mechanical analyses of soils by the hydrometer method. Soil Sci. 42:225–229.

Braun, E. L. 1964. Deciduous forest of Eastern North America. Hafner Publishing Co. New York, N.Y. 596 pp.

Bray, J. R., and E. Gorham. 1964. Litter production in forests of the world. *In*: Adv. Ecol. Res. (J. B. Cragg, ed.) 2:101–157.

Curtis, R. T., and R. P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32: 476–496.

Foth, H. D., and H. S. Jacobs. 1964. Laboratory manual for introductory soil science. Wm. C. Brown Co. Dubuque, Ia.

Gleason, H. A., and A. Cronquist. 1963. Manual of vascular plants of Northeastern United States and adjacent Canada. D. Van Nostrand Co. Princeton, N.J. 810 pp.

Gorin, F. 1876. Barren County, Kentucky. Reprinted in 1926 entitled "Times of Long Ago" by J. P. Morton Co. Louisville, Ky. 131 pp.

Hussey, J. 1876. Report of the botany of Barren and Edmonson Counties. Ky. Geol. Surv. 1:27–58.

Latham, E. E. 1969. Soil survey of Barren County, Kentucky. U.S. Government Printing Office. Washington, D.C. 85 pp.

Lindsey, A. A., J. D. Barton, Jr., and S. R. Miles. 1958. Field efficiency of forest sampling methods. Ecology 39:428–444.

McFarlan, A. C. 1943. Geology of Kentucky. Univ. Ky. Lexington, Ky. 531 pp.

Monk, C. D., and J. T. McGinnis. 1966. Tree species diversity in six forest types in north central Florida. J. Ecol. 54:341–344.

Oosting, H. J. 1956. The study of plant communities. W. H. R. Freeman Co. San Francisco, Calif. 440 pp.

Shaler, N. S. 1884. Kentucky, a pioneer commonwealth. Houghton Mifflin Co. New York, N.Y. 433 pp.

Wilhm, J. L., and T. C. Dorris. 1968. Biological parameters for water and quality criteria. Bioscience 18:477–481.

Williams, C. B. 1964. Pattern in the balance of nature, and related problems in quantitative ecology. Academic Press, New York, N.Y. 324 pp.

Mussels of the Green River, Kentucky

Billy G. Isom

Environmental Biology Branch, Division of Environmental Planning,
Tennessee Valley Authority, Muscle Shoals, Alabama 35660

Abstract

Seventy-seven species of unionid mussels and the Asiatic clam (*Corbicula*) are listed from the Green River, Kentucky, and an additional species from a nearby pond. These data further confirm the conclusions of Ortmann (1926) and Clench and van der Schalie (1944) that the mussels in the Green River belong to either the Ohioan or the interior basin fauna or are of unknown origin. No mussels of Cumberlandian origin have ever been found in the Green River.

The Green River Basin presently has one of the most diverse mussel faunas of any stream in the country. Historically, Ortmann (1926) synthesized known information on mussel fauna of the Green River, Kentucky, drainage. A compilation of historical and recent collections of mussels include those by Ortmann (1926), Clench and van der Schalie (1944), Stansbery (1965), Williams (1969), collections by Isom in 1970 and 1971, and collections in 1961 and 1965 by personnel of the Academy of Natural Sciences of Philadelphia in the vicinity of the Paradise Steam Plant between Miles 82 and 108 on the Green River under contract with the Tennessee Valley Authority (Table 1). Subspecific designations in Table 1 were retained for the purpose of comparing current data with historical records; however, in the opinion of the author, subspecific designations noted are questionable.

The records of Isom, Stansbery, and Williams probably represent the presently known fauna of the Green River Basin. These rather extensive collections include 77 species and confirm that the mussels in the Green River belong to either the Ohioan or the interior basin fauna or are of unknown origin and also confirm the absence of mussels of Cumberlandian origin as noted by Ortmann (1926) and Clench and van der Schalie (1944).

Recently there has been some concern about the mussel fauna of the Green River because of the development of oil fields. Imlay (1971) indicated that potassium contained in "petroleum brine waste" had ruined the commercial mussel harvest from Green River. Based on observations made by Isom in 1970 and 1971 and those by Williams (1969), it is apparent that there is no correlation between mussel populations in the Green River and the presence of potassium from petroleum brine waste. Williams (1969) stated that, "Good beds of living mussels were found just below all dams on the river with the exception of Dam 2 at Calhoun, Kentucky." He noted that the present Dam 2 was relatively new and was relocated downstream of an original structure that accounted, at least in part, for lack of mussels. In addition, some commercial mussels were harvested on the Green River in 1965, about 5 years after the problem of oil well brine waste was reportedly alleviated.

Data on water quality indicate that potassium levels do not exceed 3 mg/l between Miles 81.8 and 108.0 on the Green River; this is less than the lowest lethal range of 4 to 7 mg/l reported by Imlay (1971) for long-term exposures. However, 3 mg/l could well be exceeded elsewhere in the drainage.

Williams (1969) included *Lampsilis cariosa* in his list of mussels from the Green River. This probably is an error, because the distribution of *L. cariosa* is confined to streams of the Atlantic coast

TABLE 1.—MUSSEL FAUNA OF THE GREEN RIVER IN KENTUCKY, AS SHOWN BY HISTORICAL AND RECENT COLLECTIONS. O = ORTMANN (1926), S = STANSBERY (1965), C = CLENCH AND VAN DER SCHALIE (1944), W = WILLIAMS (1969), AND I = ISOM (COLLECTIONS OF 1970, 1971; AND IN 1961 BY BATES AND 1965 BY FULLER OF THE PHILADELPHIA ACADEMY OF NATURAL SCIENCES)

Species	Collector
Cumberlandia monodonta (Say)	– S – – –
Fusconaia undata Ort.	– – C W I
Fusconaia ebenus (Lea)	O – – W –
Fusconaia flava (Raf.)	O S C W –
Fusconaia flava trigona (Lea)	O – – – –
Fusconaia subrotunda (Lea)	O S C W I
Fusconaia subrotunda kirtlandiana (Lea)	O – – – –
Megalonaias gigantea (Bar.)	O S C W I
Amblema costata Raf.	O S C W I
Amblema costata peruviana (Lam.)	O – C – –
Quadrula quadrula (Raf.)	O S C W –
Quadrula pustulosa (Lea)	O S C W I
Quadrula nodulata (Raf.)	– – C W –
Quadrula metanevra (Raf.)	O S – W I
Quadrula metanevra wardi (Lea)	O – – – –
Quadrula cylindrica (Say)	O S C W –
Tritogonia verrucosa (Raf.)	O S C W I
Cyclonaias tuberculata (Raf.)	O S C W I
Cyclonaias tuberculata granifera (Lea)	O – – – –
Plethobasus cooperianus (Lea)	O – C – –
Plethobasus cyphyus (Raf.)	O S – W –
Pleurobema clava (Lam.)	O S C W –
Pleurobema cordatum cordatum (Raf.)	O S C W I
Pleurobema cordatum plenum (Lea)	O – – W –
Pleurobema cordatum coccineum (Con.)	O S C W –
Pleurobema cordatum pyramidatum (Lea)	O S C – –
Pleurobema cordatum catillus (Con.)	O S C – –
Elliptio crassidens (Lam.)	O S C W I
Elliptio dilatatus (Raf.)	O S C W –
Lastena lata (Raf.)	O S – – –
Arcidens confragosus (Say)	O – C W –
Lasmigona costata (Raf.)	O S C W –
Lasmigona complanata (Barnes)	– – C W I
Anodonta imbecillis (Say)	O – C – I
Anodonta grandis (Say)	O – C – –
Anodonta suborbiculata (Say)	O – – – –
Anodontoides ferussacianus (Lea)	O – – W –
Alasmidonta calceolus (Lea)	O S C – –
Alasmidonta marginata (Say)	O S C – –
Strophitus undulatus (Say)	O S C – –
Simpsoniconcha ambigua (Say)	– S – – –
Ptychobranchus fasciolaris (Raf.)	O S C W I
Obliquaria reflexa (Raf.)	O – C W I
Cyprogenia irrorata (Lea)	O – C – –
Obovaria olivaria (Raf.)	– – – W –

TABLE 1. *Continued*

Species	Collector
Obovaria subrotunda (Raf.)	O S C – I
Obovaria subrotunda lens (Lea)	O – – – –
Obovaria retusa (Lam.)	O S – W –
Actinonaias carinata (Bar.)	O S C W –
Truncilla truncata (Raf.)	O S C W –
Truncilla donaciformis (Lea)	O – C W I
Plagiola lineolata (Raf.)	O – C W I
Leptodea fragilis (Raf.)	O S C – –
Leptodea leptodon (Raf.)	– S – – –
Leptodea laevissima (Lea)	– S – W I
Proptera alata (Say)	O S C W I
Proptera capax (Green)	– – – W –
Carunculina parva (Bar.)	O S – W –
Carunculina glans (Lea)	O – C – –
Ligumia recta (Lam.)	O S C W I
Ligumia subrostrata (Say)	O – – – –
Villosa fabalis (Lea)	O S – – –
Villosa nebulosa (Con.)	O – – – I
Villosa ortmanni (Walker)	O S C – I
Villosa lienosa (Con.)	O S C – I
Lampsilis anodontoides (Lea)	O S C W I
Lampsilis anodontoides fallaciosa (Smith)	O – C W –
Lampsilis radiata siliquoidea (Bar.)	O S C W I
Lampsilis luteola (Lam.)	– – – W –
Lampsilis ovata ovata (Say)	O S C W –
Lampsilis ovata ventricosa (Bar.)	O S C – I
Lampsilis fasciola (Raf.)	O S C – –
Dysnomia triquetra (Raf.)	O S C W –
Dysnomia sulcata (Lea)	– – C – –
Dysnomia torulosa (Raf.)	O S – – –
Dysnomia torulosa gubernaculum (Reeve)	O – – – –
Dysnomia flexuosa (Raf.)	O – – – –
Corbicula manilensis Philippi	– – – W I

drainage (Simpson 1914). Williams (1969) listed *Lampsilis fallaciosa* and *Actinonaias ligamentina*, but these are listed in this paper as *L. anodontoides fallaciosa* and *A. carinata*, respectively.

Mussels collected by Isom are deposited at the University of Michigan at Ann Arbor, those collected by Bates and Fuller for the Academy of Natural Sciences of Philadelphia are deposited at the Academy, and those collected by Williams are deposited at The Ohio State Museum at Columbus.

Henry van der Schalie, Curator, Mollusk Division, University of Michigan, confirmed

identification of some mussels collected from the Green River by the author.

LITERATURE CITED

CLENCH, W. J., AND H. VAN DER SCHALIE. 1944. Notes on naiades from the Green, Salt, and Tradewater Rivers in Kentucky. Mich. Acad. Sci., Arts, Lett., pp. 223–228.

IMLAY, M. 1971. Bioassay tests with naiads. Proceedings of a symposium on rare and endangered mollusks (naiads) of the U.S. U.S. Dept. Interior, pp. 38–41.

ORTMANN, A. E. 1926. V. The naiades of the Green River drainage in Kentucky. Ann. Carnegie Mus. 17(1):167, 188.

SIMPSON, C. T. 1914. A descriptive catalogue of the naiades or pearly fresh-water mussels. Published by Bryant Walker, Detroit, Mich., 1,540 pp.

STANSBERY, D. H. 1965. The naiad fauna of the Green River at Munfordville, Kentucky. Amer. Malacol. U. Ann. Rept. 1965:13–14.

WILLIAMS, J. C. 1969. Mussel fishery investigation, Tennessee, Ohio, and Green Rivers, final report, Murray State University, Biological Station, State of Ky. Proj. No. 4-19-R, 107 pp.

NEWS AND COMMENT

News and Comment This column will be carried regularly in the forthcoming issues of the TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE. It will provide a vehicle for all members of the Academy to offer noteworthy news and comments to their fellow members.

* * * * *

New Format This is the first issue of the TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE in its new format as authorized by the Executive Committee of the Academy. The Committee and the Editors will appreciate receiving your comments, either pro or con.

It is anticipated that the TRANSACTIONS will continue to be issued twice a year with Numbers 1 and 2 as a single issue and Numbers 3 and 4 as a single issue. Deadlines for receipt of manuscripts in their final revised form will be 1 April for Numbers 1 and 2, and 1 October for Numbers 3 and 4.

We ask your indulgence for the tardiness of this first issue. That delay was caused primarily by the combined changes in format, change in printer, and change in editorial staff. From now on, since we believe that most of the wrinkles have been ironed out, we will make every effort to keep on schedule.

As in the past, all manuscripts received will be reviewed by competent scientists in the discipline concerned, and all correspondence will be answered promptly.

All orders for reprints will be handled through the Editors with all payments to be made directly to The Allen Press, Lawrence, Kansas 66044. Orders for reprints by institutions should include a proper purchase order number. This change in policy will relieve the Secretary and Treasurer of these tasks.

* * * * *

1974 Meeting The next meeting of the Academy is scheduled for 1 and 2 November 1974, at Centre College, Danville, Kentucky. Make your reservations early.

EDITOR'S NOTE

As a matter of editorial policy, all measurements in papers submitted for publication in the TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE should either be in the metric system or should carry metric equivalents in parentheses. Some of the more common equivalents for weights and measures are listed below.

Length:—

1 inch	= 2.540 centimeters
1 foot	= 30.480 centimeters
1 yard	= 0.9144 meter
1 mile	= 1.6093 kilometers
1 centimeter	= 0.3937 inch
1 meter	= 3.2808 feet
1 meter	= 1.0936 yards
1 kilometer	= 0.6214 mile
1 foot per mile	= 0.1894 meter per kilometer

Area:—

1 square inch	= 6.452 square centimeters
1 square foot	= 0.0929 square meter
1 square yard	= 0.8361 square meter
1 square mile	= 2.590 square kilometers
1 square centimeter	= 0.1550 square inch
1 square meter	= 10.76 square feet
1 square kilometer	= 0.3860 square mile
1 square kilometer	= 247.10 acres
1 acre (43,560 feet^2)	= 4,046.48 square meters
1 square foot per acre	= 0.03759 square meter per hectare
1 hectare	= 10,000 square meters

Volume and Capacity:—

1 cubic inch	= 16.39 cubic centimeters
1 cubic foot	= 28.31625 liters
1 cubic foot	= 7.48 gallons (U.S.)
1 gallon (U.S.)	= 0.1337 cubic foot
1 gallon (U.S.)	= 3.7853 liters
1 milliliter	= 1.000028 cubic centimeters
1 milliliter	= 0.061 cubic inch
1 acre foot (43,560 feet^3)	= 1,233.49 cubic meters

Weight:—

1 ounce	= 28.349 grams
1 pound	= 453.59 grams
1 kilogram	= 2.2046 pounds
1 pound per acre	= 0.18357 kilograms per hectare

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and, once accepted, an attempt will be made to publish papers in the order of their acceptance. Manuscripts should be typed, double spaced throughout, on good quality white paper 8½ × 11 inches (216 × 279 mm). The original and one copy should be sent to the Editor and the author should retain a copy for his own use in correcting proof. Metric and Celsius units are to be used for all measurements instead of, or in addition to, English and Fahrenheit units. Format and style may vary somewhat depending on the scientific discipline, but the basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of papers in the Journals of the American Chemical Society, the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and A Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined.

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Darlington, P. J., Jr. 1965. Biogeography of the southern end of the world. Harvard Univ. Press, Cambridge, Mass. 236 pp.

5. Each table, together with its heading, must be double spaced, numbered in arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print about 5 × 7 inches. Line drawings in India ink on white paper are acceptable. Photographs should have good contrast so that they can be reproduced satisfactorily. Figures should be numbered in arabic numerals.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and such costs are to be borne by the author. Reprints are to be ordered when the galley proofs are returned to the Editor.

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Substrate Preference of Benthic Macroinvertebrates in Silver Creek, Madison County, Kentucky

Catherine B. Crisp and Norman H. Crisp

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Field collections of benthic macroinvertebrates were taken with a square-foot Surber stream bottom sampler on 3 different types of substratum during August, September, and October 1973 on 4 occasions in order to determine the respective species diversity and percentage composition. The boulder substrate was the most productive, followed by the rubble, with sand and gravel the least productive. Thirteen orders and 20 genera of bottom organisms were identified, but a few genera made up the bulk of the standing crops for each station. *Stenonema* and *Isonychia* formed the majority of the ephemeropteran nymphs, *Cheumatopsyche* and *Hydropsyche* comprised over half the trichopterans, *Pentaneura* larvae accounted for most dipterans, and *Stenelmis* made up a large percentage of the Coleoptera. The data include prechannelization and postchannelization conditions. Standing crop for each station was similar before channelization, but afterwards the respective mean numbers declined.

Introduction

Substrate preference of macroinvertebrates was studied in a portion of Silver Creek, Madison County, near Richmond, Kentucky. Silver Creek is a permanent stream with a dendritic drainage pattern. Elevation at Station 1 is 210 m above mean sea level (msl). At Stations 2 and 3, the elevation is 204 m msl. Average gradient within the study area is 9.5 m/km. The 3 riffle stations selected for collection are all within fairly close proximity (0.64 km) of each other on Barnes Mill Road, Madison County. Physical characteristics for each station are shown in Table 1; the upstream and downstream boundaries for each station encompassed approximately 15–18 m.

Collections of aquatic macroinvertebrates were made on 4 occasions, 13 August, 1 September, 4 October, and 21 October 1972, at the 3 stations in an attempt to determine species density and percentage composition with respect to 3 different types of stream substrate. Substrates were considered as follows: boulders, rocks 30 cm or more in diameter; rubble, 7.5–30 cm; and sand and gravel, less than 7.5 cm. Other workers (Pennak and Van Gerpen 1947) used bedrock as a representative of the boulder type substrate, a type not investigated during this study.

During the week including 25 September, a portion of Silver Creek, involving Stations 2 and 3 was channelized. Therefore, the first 2 collections (13 August and 1 September) represent conditions prior to channelization, while the latter 2 (4 and 21 October) represent those after channelization.

Methods and Materials

A square-foot (0.093 m^2) Surber bottom sampler was utilized for taking quantitative samples. Three samples were taken from

TABLE 1.—SOME PHYSICAL PARAMETERS OF COLLECTION STATIONS IN SILVER CREEK

Parameters	Station 1 (boulder)	Station 2 (sand and gravel)	Station 3 (rubble)
Mean Velocity (m/sec)	0.54	0.20	0.67
Mean Depth (m)	0.12	0.09	0.21
Mean Width (m)	10.06	3.90	3.66
Channel Size (m^2)	1.18	0.36	0.77

each type of substrate on each visit, for a total of 36 samples during the study period. Sampling was random along the 15–18 m length and over the entire width of each station in order to minimize sampling errors caused by differences in production potential within each station. The benthos were counted and identified following the keys of Pennak (1953) and Ward and Whipple (Edmonson 1959), Burks (1953), Ross (1953), and Usinger (1956). Ephemeropteran nymphs in very early stages of development were too small for positive identification.

Channel size (Table 1) or area of cross section of stream basin, was calculated for each station, based on the formula $A = d_m - w$ (Reid 1961). Mean depths and velocity were determined with a Gurley current meter.

RESULTS

Ephemeropteran nymphs comprised the greatest percentage of the total number of benthos (Table 2) and were most abundant on the boulder substrate (53.51%), and least abundant on sand and gravel (8.69%, Table 4). Ephemeropteran nymphs were by far the most abundant benthic organisms on rubble, with an average percentage occurrence of 56.72 (Table 2). *Stenonema* was the most abundant genus in rubble but was scarce on sand. *Isonychia*, however, consistently occurred at moderate density on each substrate but was lower in overall abundance (Table 3). Four other genera (*Heptagenia*, *Caenis*, *Baetis*, and *Paraleptophlebia*) were present in smaller numbers at each station with the exception of *Paraleptophlebia* which occurred only on boulders.

TABLE 2.—AVERAGE PERCENTAGE OF THE FAUNA AND TOTAL DENSITY COLLECTED AT EACH STATION

Taxon	Station 1 (boulder)		Station 2 (sand and gravel)		Station 3 (rubble)	
	%	No.	%	No.	%	No.
Ephemeroptera	40.5	351	15.6	57	56.7	248
Trichoptera	17.2	149	19.4	71	23.5	129
Neuroptera	0.7	6	0.6	2	0.2	1
Diptera	6.1	53	3.8	14	4.2	23
Coleoptera	10.7	93	24.0	88	15.7	86
Plecoptera	0.2	2	0.0	0	0.4	2
Hemiptera	0.1	1	0.0	0	0.0	0
Odonata	0.4	3	0.0	0	0.7	4
Gastropoda	20.1	174	32.5	119	7.3	40
Pelecypoda	0.6	5	3.3	12	0.2	1
Isopoda	2.1	18	0.0	0	0.9	5
Decapoda	0.7	6	0.0	3	1.6	9
Turbellaria	0.7	6	0.0	0	0.0	0
Total		867		366		549
Mean no./m^2	6.71		3.75		4.25	

Trichopterans, the second most abundant insect order were taken from all 3 substrates, being most abundant on boulders (Table 4) and least abundant on sand and gravel. At Station 3 (rubble), Trichoptera were the second most abundant taxa, averaging 23.5 percent of the total fauna (Table 2). *Cheumatopsyche* was the most abundant caddisfly, with a decreasing relative abundance from boulders to sand to rubble (Table 3). *Hydropsyche*, however, was most abundant on rubble, boulders, and sand, respectively. *Chimarra*, ranking third in trichopteran abundance, was found in fairly consistent numbers on each substrate. Both *Polycentropus* and *Diplectrona* were found on each substrate in small numbers only; however, their greatest density per square meter was on the boulder substrate.

Corydalus was the only representative of the order Neuroptera (Megaloptera) present, being most prevalent on boulders where the velocity was high, and least abundant on the sand and gravel substrate (Table 3). *Corydalus* accounted for only a small percentage of the total (Table 2).

TABLE 3.—MEAN NUMBER OF GENERA PER SQUARE METER ON DIFFERENT TYPES OF SUBSTRATE AT COLLECTING STATIONS

Taxon	Station 1 (boulder)	Station 2 (sand and gravel)	Station 3 (rubble)
Ephemeroptera			
Isonychia	1.07	0.38	0.51
Stenonema	1.23	0.03	0.90
Heptagenia	0.03	0	0.21
Caenis	0.16	0.03	0.22
Baetis	0.27	0.02	0.07
Paraleptophlebia	0.06	0	0
Trichoptera			
Hydropsyche	0.29	0.13	0.37
Cheumatopsyche	0.62	0.55	0.26
Chimarra	0.18	0.14	0.26
Polycentropus	0.05	0.01	0.01
Diplectrona	0.03	0.01	0.01
Neuroptera			
Corydalus	0.05	0.02	0.03
Diptera			
Pentaneura	0.11	0.39	0.17
Simulium	0.01	0.02	0.01
Coleoptera			
Psephenus	0.32	0.39	0.25
Stenelmis	0.39	0.28	0.34
Plecoptera			
Acroneuria	0.02	0	0.02
Hemiptera			
Platygerris	0.01	0	0
Odonata			
Argia	0.03	0	0.03
Gastropoda			
Pleurocera	1.31	0.92	0.33
Physa	0.03	0	0.03
Pelecypoda			
Sphaerium	0.04	0.10	0.01
Isopoda			
Lirceus	0.14	0	0.03
Decapoda			
Orconectes	0.04	0.03	0.04
Turbellaria			
Dugesia	0.04	0	0

TABLE 4.—PERCENTAGE OCCURRENCE OF MACROINVERTEBRATE ORDERS AT EACH COLLECTING STATION

Taxon	Station 1 (boulder)	Station 2 (sand and gravel)	Station 3 (rubble)
Ephemeroptera	53.5	8.7	37.8
Trichoptera	42.7	20.3	37.0
Neuroptera	66.7	22.2	11.1
Diptera	58.8	15.6	25.6
Coleoptera	34.8	33.0	32.3
Plecoptera	50.0	0	50.0
Hemiptera	100.0	0	0
Odonata	50.0	0	50.0
Gastropoda	52.2	35.7	12.0
Pelecypoda	27.0	66.7	6.3
Isopoda	78.3	0	21.7
Decapoda	33.0	16.7	50.0
Turbellaria	100.0	0	0

Only 2 dipterans were found, both being most abundant on boulders (Table 3). *Pentaneura* was the most abundant, having a mean number of 0.1, 0.4, and 0.2 per square meter on boulders, sand and gravel, and rubble, respectively (Table 3). *Simulium* was present on all substrates but was most abundant on sand.

The order Coleoptera was represented by 2 genera, *Psephenus* and *Stenelmis*, both being most abundant on boulders (Table 3). Both adults and larvae of *Stenelmis* were decreasingly abundant on boulders, rubble, and sand and gravel, respectively, whereas larval *Stenelmis* were more abundant than adults on sand.

Acroneuria, the only plecopteran found, was equally abundant on boulders and rubble, but lacking on sand and gravel.

Platygerris, the only hemipteran encountered, was collected at the boulder station only on 21 October 1972.

Argia, the only representative of damselflies collected, was equally distributed on boulders and rubble, but was absent from sand and composed only a small percentage of the total fauna.

Gastropods represented 20.07 percent of the fauna for the boulder substrate, 32.51 percent for sand, and 7.29 percent for rubble. These percentages were largely a result of the abundance of one snail, *Pleurocera*, which averaged 1.3, 0.9, and 0.3 per square meter on boulder, sand and gravel, and rubble, respectively. *Physa* was present on boulders and rubble in relatively low density, but was absent from the sand and gravel station.

The only pelecypod found, *Sphaerium*,

TABLE 5.—TOTAL AND MEAN BENTHIC STANDING CROP PER STATION (TWELVE SAMPLES WERE TAKEN FROM EACH STATION)

	Before Channelization				After Channelization			
	13 Aug		1 Sep		4 Oct		21 Oct	
	Total No.	Mean No./m²	Total No.	Mean No./m²	Total No.	Mean No./m²	Total No.	Mean No./m²
Station 1 (boulder)	132	4.09	180	5.58	239	7.41	317	9.83
Station 2 (sand and gravel)	130	4.03	186	5.75	—	—	44	1.36
Station 3 (rubble)	151	4.68	170	5.39	102	3.16	124	3.84

was decreasingly abundant on sand and gravel, boulders, and rubble, respectively.

Lirceus, an isopod crustacean, composed a very minute portion of the total fauna, being present only on boulders and rubble, most abundant on the first (Table 3). *Lirceus* appeared only in the last 2 collections following the decrease in water temperature.

Orconectes was less abundant on sand than on the boulder and rubble substrates, with the average percentage of the fauna being highest on the rubble substrate (Tables 2, 3).

At the boulder station, where the velocity was maximum, *Dugesia* was collected but was present only in the last 2 collections.

DISCUSSION

Although 13 orders and 20 genera of invertebrates were identified during this study, a few genera composed the bulk of the standing crops for each station. *Stenonema* and *Isonychia* formed the majority of the ephemeropteran nymphs. *Cheumatopsyche* and *Hydropsyche* comprised over half the Trichoptera. *Pentaneura* larvae accounted for most Diptera. *Stenelmis* made up a large percentage of the Coleoptera.

Standing crop for each station did not vary appreciably before channelization (Table 5). However, following channelization, the mean number of organisms per square meter declined while the standing crop for Station 1 (not channelized) increased (Fig. 1). A reasonable explanation for this rise in number for Station 1 is the occurrence of fall peaks in the life cycles of many of the insects. Most of the insects of streams have an annual turnover (Armitage 1958). Needham (1934) found the greatest seasonal abundance in both numbers and weight in May and a lesser peak of abundance in November during a mild winter. Maciolek and Needham (1951) reported an August low and a February high. Stehr and Branson (1938) reported the greatest density in the fall. This study was too limited in duration to indicate the seasonal course of the life cycles of the various species.

The varied habitat preferences for respective genera within reasonable sampling errors are evident from the data in Table 3. The baetid, *Isonychia*, for instance, is evidently better adapted, with its coxal gills and fringes of hair on the forelegs, to exist on varied substrates, while *Stenonema* (Heptageniidae) is less able to maneuver on sand, and prefers to cling to large flat rocks. As a group, the Ephemeroptera seemed to be adapted to a wider range of current speed and exposure in stream habitats than other insects collected. The trichopteran, *Cheumatopsyche*, exhibited an approximate 2:1 ratio in abundance over *Hydropsyche* within the same habitat. Interspecific competition probably is present between these species, *Cheumatopsyche* being better able to compete for available nutrients and space. Plecopteran nymphs were collected only from the surfaces of

rubble and boulders where they were protected from abrasion and the swiftest current.

In viewing the total productivity of each substrate studied, the boulder substrate was the most productive followed by the rubble, with sand and gravel the least productive (Tables 2, 5, Fig. 2). The mean number of organisms per square meter was plotted against the median particle size of each substrate type and the regression line found using the criteria of Freund (1970). This indicated a positive correlation between mean number of organisms per square meter and substrate type. Since the coefficient of correlation (r) between the number of organisms and substrate types was 0.602 and the critical value for r is 0.611 (Freund 1970) at the 95 percent confidence level, it can be assumed that particle size is a determining factor in distribution of the benthos for the portion of Silver Creek studied. This is reasonable since boulders and rubble provided more space and more diverse habitats than a sand and gravel substrate.

Studies by Needham (1928, 1929, 1934), Behney (1937), Pate (1932, 1934), Pennak and Van Gerpen (1947), Percival and Whitehead (1929), and Sprules (1947) all concur with this study in indicating a higher standing crop in numbers on rubble than on gravel.

Following channelization of Stations 2 and 3 during the week of 25 September, there was a marked decrease in the fauna at those locations. This decrease can only be attributed to channelization since Station 1 did not show a similar decrease (Table 5, Fig. 1). Station 2 was drastically affected by channelization; however, a small-scale *t*-test demonstrated that there was a significant difference between surveys before and after channelization at Station 3.

This reduction of the fauna following habitat alteration is similar to that found by Meehan (1971) in Alaskan streams. Waters (1964), however, found that denuded bottom areas were often repopulated within 24 hours. Since he reported that drift was the most important factor in recolonization and drift is greater in fall, the communities of Stations 2 and 3 should have returned to the prechannelization level during the study period. Since the prechannelization density level was not reached in the relatively long section of the channelized stream, recolonization may have proceeded in a gradual manner down the length of the denuded stream. Thus, the portions of the stream in close proximity to the nonchannelized sections probably were rapidly recolonized, and areas farther from

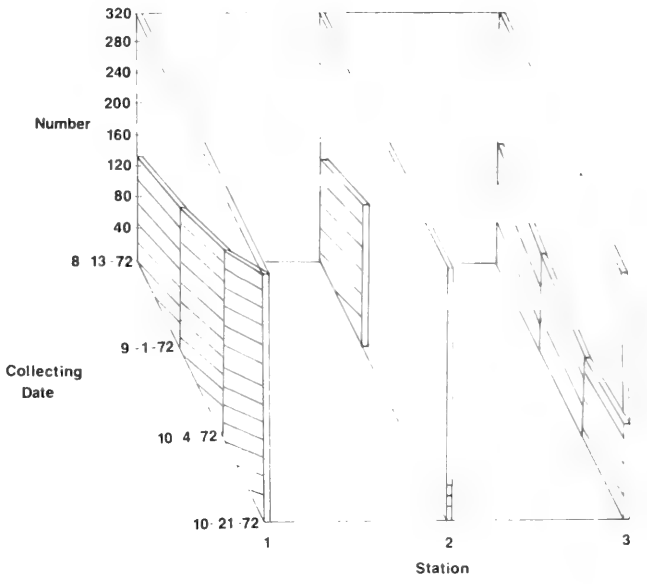


FIG. 1. Total number of benthos collected at each station on successive collecting dates.

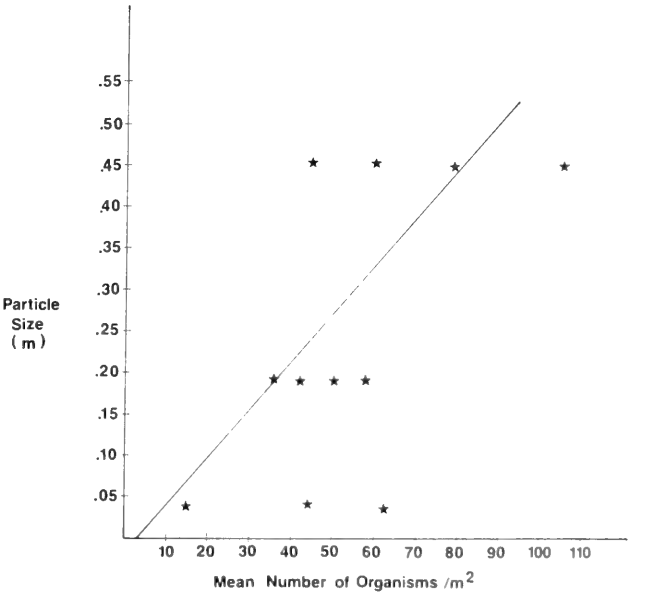


FIG. 2. Relationship between particle size and number of organisms per square meter.

the nonaffected areas would be recolonized last.

LITERATURE CITED

ARMITAGE, K. B. 1958. Ecology of the riffle insects of Firehole River, Wyoming. Ecology 39(4):571–580.

BEHNEY, W. H. 1937. Food organisms of some New Hampshire trout streams. *In* Biological Survey of the Androscoggin, Saco and Coastal watersheds. Surv. Rept. No. 2. N. H. Fish & Game Dept., pp. 77–80.

BURKS, B. D. 1953. The mayflies, or Ephemeroptera, of Illinois. Bull. Ill. Nat. Hist. Surv. 26(1):1–216.

EDMONSON, W. T. (Ed.) 1959. Ward and Whipple's Fresh-Water Biology. John Wiley and Sons, Inc., New York, N.Y. 1248 pp.

FREUND, J. E. 1970. Statistics, a first course. Prentice-Hall, Inc., Englewood Cliffs, N.J. 304 pp.

MACIOLEK, J. A., AND P. R. NEEDHAM. 1951. Ecological effects of winter conditions on trout and trout foods in Convict Creek, California. Trans. Amer. Fish. Soc. 81:202–217.

MEEHAN, W. R. 1971. Effects of gravel cleaning on bottom organisms in three southeastern Alaskan streams. Prog. Fish. Cult. 33(2): 107–111.

NEEDHAM, P. R. 1928. Quantitative studies of the fish food supply in selected areas. A biological survey of the Oswego River System. N.Y. State Cons. Dept., Suppl. 17th Ann. Rept. pp. 220–232.

———. 1929. Quantitative studies of fish food supply of selected areas. A biological survey of the Erie–Niagara system. Suppl. 18th Ann. Rept. N.Y. State Cons. Dept. pp. 220–232.

———. 1934. Quantitative studies of stream bottom foods. Trans. Amer. Fish. Soc. 64: 238–247.

PATE, V. S. L. 1932. Studies on fish food supply in selected areas. A biological survey of the Oswegatchie and Black River systems. Suppl. 21st Rept. N.Y. Cons. Dept. pp. 133–149.

———. 1934. Studies on fish food supply in selected areas of the Raquette watershed. A biological survey of the Raquette watershed. Suppl. 23rd Ann. Rept. N.Y. State Cons. Dept. pp. 136–157.

PENNAK, R. W. 1953. Freshwater Invertebrates of the United States. Ronald Press, New York, N.Y. 769 pp.

———, AND E. D. VAN GERPEN. 1947. Bottom fauna production and physical nature of the substrate in northern Colorado trout streams. Ecology 28:42–48.

PERCIVAL, E., AND H. WHITEHEAD. 1929. A quantitative study of the fauna of some types of stream-bed. J. Ecol. 17:283–314.

REID, G. K. 1961. Ecology of Inland Waters and Estuaries. Van Nostrand Reinhold Co., New York, N.Y. 375 pp.

ROSS, H. H. 1953. The caddisflies, or Trichoptera, of Illinois. Bull. Ill. Nat. Hist. Surv. 23: 1–326.

SPRULES, W. M. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Stud. 56:1–81.

STEHR, W. C., AND J. W. BRANSON. 1938. An ecological study of an intermittent stream. Ecology 14(2):294–310.

USINGER, ROBERT L. 1956. Aquatic Insects of California. Univ. Calif. Press, Berkeley, Ca. 508 pp.

WATERS, T. F. 1964. Recolonization of denuded stream bottom areas by drift. Trans. Amer. Fish. Soc. 93:311–315.

Synthesis of *p*-[*N*′,*N*′-Bis(2-chloroethyl)amino]-*N*-sulfinylaniline.

WALTER T. SMITH, JR. AND JAMES A. KUHLENSCHMIDT
Department of Chemistry, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

The title compound, an analog of antitumor compounds related to nitrogen mustard, has been synthesized by reaction of *N*,*N*-bis(2-hydroxyethyl)aniline with phosphorus oxychloride followed by nitrosation of the product with nitrous acid; then reduction of the *N*,*N*-bis(2-chloroethyl)-*p*-nitrosoaniline to the corresponding amine hydrochloride, and subsequent reaction of the dichloroamine hydrochloride with thionyl chloride to give *p*-[*N*′,*N*′-bis(2-chloroethyl)amino]-*N*-sulfinylaniline.

INTRODUCTION

In previous work we have synthesized sulfinylamino derivatives (Ib) of nitrogen mustard (Ia).

$$(ClCH_2CH_2)_2N\text{-}R$$

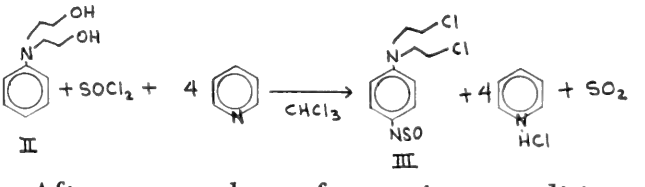
a,R = CH_3 b,R = NSO

I

These compounds showed varying degrees of antitumor activity. Of special interest was *N*′,*N*′-bis(2-chloroethyl)-*N*-sulfinylhydrazine(Ib), which is active against Walker carcinosarcoma 256 at the 1.6 mg/kg level and in cell culture cytotoxicity tests had an ED_{50} of 6.6 mg/ml (Smith and Chen 1968). As part of a program to modify this active structure, we have synthesized *p*-[*N*′,*N*′-bis(2-chloroethyl)amino]-*N*-sulfinylaniline. This structure may be thought of as compound Ib in which a benzene ring has been inserted between the nitrogens of the hydrazine moiety.

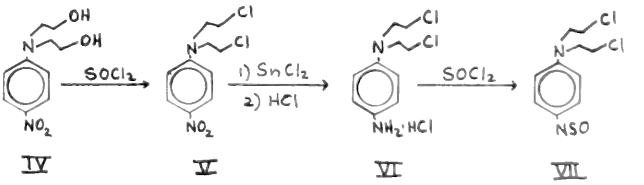
METHODS

The initial approach to the synthesis of this compound was designed to keep the number of synthetic steps to a minimum. *N*,*N*-Bis(2-hydroxyethyl)-*p*-nitroaniline was prepared by reaction of 1-chloro-4-nitrobenzene with 2,2′-iminodiethanol. The somewhat low yield obtained in this step was offset by the commercial availability of the reagents. Catalytic reduction of the nitro group readily converted the nitro group to an amino group but considerable difficulty was encountered in obtaining the amino compound in a pure state, due to its very rapid oxidation in air. This problem was eventually overcome by keeping the product as free from oxygen as possible. This entailed the bubbling of nitrogen through the ethanolic solution of the compound during any pauses in the isolation procedure. It was found that *N*,*N*-bis(2-hydroxyethyl)-*p*-phenylenediamine was relatively more stable in ethereal solution and in dry crystalline form than when dissolved in ethanol. The crystalline product is preferably stored in the dark under dry nitrogen. Several attempts were made to convert the above diamine to the desired product in one step. This conversion should be possible since both the conversion of alcohols to alkyl chlorides and of aromatic amines to *N*-sulfinylamines have been accomplished by the action of thionyl chloride.



II III

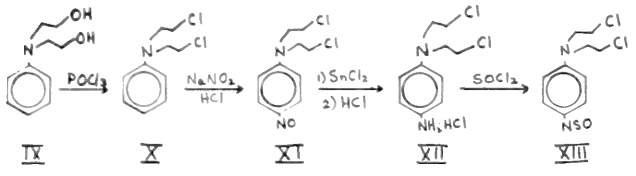
After a number of reaction conditions were found unsatisfactory for conversion of II to III in one step, it was concluded a more feasible method would be conversion first of IV to VI, then reaction of the latter with thionyl chloride to convert it to the desired *N*-sulfinyl compound (VII) as shown below.



IV V VI VII

This synthetic route was discontinued after

preparation of V using the procedure that Degutis and Bieksa (1964) used to prepare the *meta* isomer. The yield for this conversion was low and made a multistep synthetic route involving the *p*-nitro mustard (V) less desirable. It was then decided that *N*,*N*-bis(2-hydroxyethyl)aniline (IX) could provide a more efficient route to the desired product.



IX X XI XII XIII

The *N*,*N*-bis(2-chloroethyl)aniline (X) was prepared in reasonable yield by the method of Ross (1949). The light lavender product was reasonably stable except on long exposure to light. This aromatic mustard was then nitrosated in good yield by the method of Everett and Ross (1949). The nitroso mustard [*N*,*N*-bis(2-chloroethyl)-*p*-nitrosoaniline] (XI) was unstable on exposure to air and light for a period of several hours. The nitroso mustard was then reduced by the method of Everett and Ross (1949). The resulting phenylenediamine mustard [*N*,*N*-bis(2-chloroethyl)-*p*-phenylenediamine] (XII), was stored as the hydrochloride which is stable to both air and light, but exerted powerfully vesicant action on skin. The vesicant action of the mustard is destroyed by a 5–10 percent sodium sulfite solution. The decomposition point of the phenylenediamine mustard hydrochloride was found to be broad, ill-defined, and somewhat below that reported by Everett and Ross (1949). Evidence that the structure was correct, however, was provided by elemental analysis, nmr, and ir data.

The final, desired product, *p*-[*N*′,*N*′-bis(2-chloroethyl)amino]-*N*-sulfinylaniline, (XIII) was prepared by the action of a large excess of purified thionyl chloride on the phenylenediamine mustard hydrochloride under anhydrous, reflux conditions. The product was found to be unstable to atmospheric moisture and light. Nitrogen analysis and spectral data indicated that the desired product had formed. The Beilstein test showed the presence of chlorine, and a sodium fusion followed by lead acetate treatment indicated the presence of sulfur.

In view of the exceedingly poor stability of the compound to moisture and light, no attempt has been made to submit the compound for biological testing and efforts to synthesize closely related analogs have been dropped.

Experimental Section

N,N-*Bis(2-chloroethyl)*-p-*nitroaniline*.—An adaptation of the procedure used by Degutis and Bieksa (1964) in preparation of the corresponding *meta* isomer was employed.

To 5.0 g (0.022 mole) of *N*,*N*-bis(hydroxyethyl)-*p*-nitroaniline in a 250-ml single-necked flask fitted with reflux condenser, magnetic stirrer, and oil bath was added 75 ml of dry, distilled 1,2-dichloroethane and 4.5 ml (0.062 mole) of purified thionyl chloride. The mixture was refluxed with stirring 2 hours. The excess thionyl chloride and solvent were removed by evaporation under reduced pressure. The residue was treated with 100 ml of chloroform, the resulting solution was filtered, and the filtrate evaporated to dryness yielding 3.1 g (52%) of unpurified product. The crude crystals were slurried with hot absolute ethanol and removed by filtration. The resulting solid (1.2 g, 21%) melted at 192–195° C. From an analogous procedure a melting point of 198–199° corr. was obtained on recrystallization from acetone.

N,N-*Bis(2-chloroethyl)aniline*.—The procedure employed was a modification of the procedure used by Ross (1949).

N,N-*Bis(2-chloroethyl)*-p-*nitrosoaniline*.—A modification of the procedure used by Everett and Ross (1949) was employed.

N,N-*Bis(2-chloroethyl)*-p-*phenylenediamine hydrochloride*.—A larger-scaled modification of the basic procedure of Everett and Ross (1949) was used.

To 22.4 g (0.091 mole) of *N*,*N*-bis(2-chloroethyl)-*p*-nitrosoaniline dissolved in 200 ml of concentrated hydrochloric acid in a 500-ml Erlenmeyer flask equipped with stirring and cooling, 40.8 g (0.18 mole)

of stannous chloride dihydrate was added. The amine stannichloride formed as a salmon colored precipitate during the addition. The solid was removed by filtration, dissolved in water, and the solution was made slightly basic with 1*N* sodium hydroxide (ca. 1 l was required). The aqueous soln was extracted several times with ether and the combined ether layers (ca. 750 ml total) dried over sodium hydroxide pellets. Then hydrogen chloride gas was bubbled through the unstirred ether solution until lustrous silver crystals separated. The crystals were collected by filtration, and hydrogen chloride gas was then bubbled through the filtrate using caution that the brownish dihydrochloride did not separate as well. The crystalline product was dissolved in a small amount of anhydrous methanol and reprecipitated with ether and cooling to yield 12.7 g (52%). A small portion of crystals sublimed for analysis had an approximate decomposition range of 232–242 C (lit mp 250–260 C, decomp); ir (KBr) bands at 2880, 2950, 1610, 1510, 820, and 745 cm^{-1}; nmr (DMSO-d_6) 10.25 (s, broad), 7.03 (m), 3.75 ppm (*s*). It was noted that dissolution of the *N,N*-bis(2-chloroethyl)-*p*-phenylenediamine hydrochloride in tap water produced a red coloration in the water solution. Distilled water gave no noticeable coloration with the above compound. It was further observed that dilute solutions of ferric nitrate in distilled water did produce a red coloration with the above compound.

Analysis Calc'd for $C_{10}H_{15}Cl_3N_2$: C, 44.55; H, 5.61; N, 10.39. Found: C, 44.44; H, 5.68; N, 10.20.

p-*[N′,N′-Bis(2-chloroethyl)amino]-N-sulfinylaniline.*—To 1.0 ml (0.014 mole) of purified thionyl chloride dissolved in 50 ml of dry benzene in a 100-ml round-bottomed flask was slowly added 2.0 g (0.0074 mole) of *N′,N′*bis(2-chloroethyl)-*p*-phenylenediamine hydrochloride. The reaction mixture was refluxed for 2 hours on a steam bath until the solid starting material was dissolved and the solution was clear dark brown. The excess thionyl chloride and benzene were removed by evaporation to dryness under vacuum to yield 1.8 g (87%) of crude brown solid product. The product was purified by a vacuum distillation carried out in a vacuum sublimation apparatus in oil bath at 105 C bath temperature. A large amount of product is lost during the purification procedure. The purified crystalline product was yellow–orange and was found to be unstable to light and atmospheric moisture. The instability of the product required that the chemical analysis be performed on a freshly prepared and purified product obtained by procedures analogous to the above preparation. The best melting point range obtained was 78–79 C corrected; ir (KBr) bands at 2966 (very weak), 1597 (aromatic ring), 1505, 1400, 1366, 1290 (NSO), 1260, 1197, 1135 (NSO), 1018, 817, and 742 cm^{-1} (C-Cl); nmr (DMSO-d_6) 7.35 (m) and 3.82 ppm (s). On a sample obtained using 1.5 g (0.0055 mole) of the phenylenediamine mustard hydrochloride and 1.0 ml (0.014 mole) of thionyl chloride, the Beilstein test showed the presence of chlorine (green flame), and a sodium fusion with subsequent lead acetate treatment gave a brown–black precipitate of lead sulfide.

Analysis Calc'd for $C_{10}H_{12}Cl_2N_2OS$: N, 10.03. Found: N, 10.05.

LITERATURE CITED

DEGUTIS, J., AND V. BIEKSA. 1964. Synthesis of *N,N*-bis(2-chloroethyl)-*m*-phenylenediamine and its derivatives. Lietuvos TSR Aukstuju Mokyklu Mokslo Darbai, Chem. ir Chem. Technol. 4:59–64. [Chem. Abstr. 61:9417 g (1964)].

EVERETT, J. L., AND W. C. J. ROSS. 1949. Aryl-2-halogenoalkylamines. Part II. J. Chem. Soc. 1949:1972–1983.

ROSS, W. C. J. 1949. Aryl-2-halogenoalkylamines. Part I. J. Chem. Soc. 1949:183–191.

SMITH, W. T., JR., AND W. Y. CHEN. 1968. Some *N*-sulfinylhydrazine analogs of nitrogen mustard. J. Med. Chem. 11:504.

Arthropod Ectoparasites and Their Seasonal Occurrences on *Microtus ochrogaster* and *Peromyscus leucopus* From Warren County, Kentucky

RICHARD L. BUCKNER[1] AND LARRY N. GLEASON
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

A total of 150 *Microtus ochrogaster* and 155 *Peromyscus leucopus* was examined for arthropod ectoparasites from November 1970 through November 1971. Fourteen species were found on both *M. ochrogaster* and *P. leucopus*: the mites *Ornithonyssus bacoti*, *Androlaelaps fahrenholzi*, *Laelaps microti*, *Dermacarus hypudaei*, *Listrophorus leukorti*, *Mycoptes* sp., *Euschoengastia peromysci* and *Neotrombicula caviola*; the tick *Dermacentor variabilis*; the fleas *Ctenophthalmus pseudagyrtes*, *Epitedia wenmanni*, *Orchopeas leucopus*, *Peromyscopsylla scotti*, and *Stenoponia americana*. The mite *Radfordia lemnina* and the louse *Hoplopleura acanthopus* were found only on *M. ochrogaster*. The mite *Radfordia subuliger* and the louse *Hoplopleura hesperomydis* were found only on *P. leucopus*.

INTRODUCTION

Studies on the ectoparasites of the prairie vole *Microtus ochrogaster* and the wood mouse *Peromyscus leucopus* have been sporadic. Most previous studies of the parasites of these rodents have been compilations of lists of parasite species. Whitaker (1968) brought together a literature review for the genus *Peromyscus* which includes an extensive listing of both arthropod and helminth parasites. Information concerning the arthropod parasites of the prairie vole is available from scattered sources, the principal ones being Jameson (1947), Verts (1961), and Whitaker and Wilson (1968). Batson (1965), in a study of the prairie vole, listed some of the arthropod parasites for this species found in central Kentucky.

The purpose of this study was to determine the species of arthropod ectoparasites present on *M. ochrogaster* and *P. leucopus* in south-central Kentucky, to determine if the numbers of those parasites varied with seasonal changes, and to determine the extent of overlap of the parasitic species between the host species.

[1] Present address: Department of Life Sciences, University of Nebraska, Lincoln, Nebraska 68508.

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MATERIALS AND METHODS

The study area consisted of abandoned pastures and woodlots of approximately 121 hectares in size and was large enough to allow variance of trapping sites to prevent overtrapping. Located in Warren County, Kentucky, the area was approximately 0.8 km south of Bowling Green, east of US Highway 31W.

Attempts were made to trap and autopsy a minimum of 10 *Microtus ochrogaster* and 10 *Peromyscus leucopus* each month from November 1970 through November 1971. Museum Special snap traps and Hav-a-hart live traps were used. Traps were baited with a mixture of peanut butter and oatmeal. During the warm months of the year, DDT was added to the bait to prevent loss to ants (Coleman 1950). Traps were set in the evenings and checked the next morning. Dead animals were placed in individual plastic bags after removal from

TABLE 1.—ARTHROPOD ECTOPARASITES AND THEIR SEASONAL OCCURENCES ON *MICROTUS OCHROGASTER* IN WARREN COUNTY, KENTUCKY, FROM NOVEMBER 1970 THROUGH NOVEMBER 1971. THE NUMBERS IN PARENTHESES BELOW EACH SEASON AND THE TOTAL INDICATE THE NUMBER OF SPECIMENS EXAMINED. THERE WERE AT LEAST 2 KINDS OF CHIGGERS PRESENT.

Parasite	Average Number Per Host (minimum and maximum number per host)				
	Winter (32)	Spring (34)	Summer (32)	Fall (52)	Total (150)
Mites					
Ornithonyssus bacoti	0.03 (0–1)	4.23 (0–42)	71.37 (0–516)	15.36 (0–257)	23.12 (0–516)
Androlaelaps fahrenholzi	0.62 (0–4)	5.91 (0–50)	5.50 (0–31)	3.96 (0–26)	4.90 (0–50)
Laelaps microti	7.84 (0–41)	9.47 (0–119)	3.81 (0–33)	4.78 (0–34)	6.31 (0–119)
Radfordia lemnina	0	0	0.06 (0–1)	0.11 (0–1)	0.05 (0–1)
Dermacarus hypudaei	106.43 (0–1061)	315.26 (0–1695)	122.21 (7–769)	114.55 (0–597)	161.00 (0–1695)
Listrophorus leukorti	136.46 (0–1279)	49.20 (0–778)	114.37 (0–816)	510.65 (0–2169)	225.49 (0–2169)
Mycoptes sp.	1.96 (0–27)	2.70 (0–27)	0.62 (0–10)	0.96 (0–13)	1.56 (0–27)
Chiggers	11.68 (0–34)	18.23 (0–102)	0.25 (0–3)	7.07 (0–94)	8.33 (0–102)
Ticks					
Dermacentor variabilis	0.06 (0–2)	0.50 (0–9)	0.21 (0–5)	0.11 (0–1)	0.21 (0–9)
Lice					
Hoplopleura acanthopus	0.22 (0–15)	8.35 (0–72)	0	0.32 (0–21)	2.62 (0–72)
Fleas					
Ctenophthalmus pseudagyrtes	0	0.32 (0–3)	0.25 (0–3)	0.59 (0–4)	0.32 (0–4)
Epitedia wenmanni	0	0	0	0.03 (0–1)	0.01 (0–1)
Orchopeas leucopus	0.03 (0–1)	0	0	0	0.01 (0–1)
Peromyscopsylla scotti	0	0	0.03 (0–1)	0	0.01 (0–1)
Stenoponia americana	0.03 (0–1)	0.35 (0–7)	0	0.13 (0–4)	0.12 (0–7)

the traps. Live animals were killed by cervical dislocation prior to being placed in the bags.

In the laboratory, the animals were washed in a detergent solution and the pelage thoroughly brushed with a toothbrush to dislodge the ectoparasites. The plastic bag for each animal was rinsed with water and this was added to the detergent solution used to wash the animal. The mixture was then filtered through coarse filter paper. The ectoparasites were removed from the filter paper and preserved in 70 percent ethanol. Each animal was examined under a dissecting microscope and attached parasites were removed and placed with those obtained from the wash. The parasites were identified to species

where possible and the numbers of individuals of each species were recorded. Whole mount preparations were made of representative individuals of each species by mounting the specimens in Polyvinyl alcohol–lactophenol.

RESULTS

During the 13-month period of this study, 150 *Microtus ochrogaster* (77 males and 73 females) and 155 *Peromyscus leucopus* (77 males and 78 females) were examined for ectoparasites. The number of *M. ochrogaster* trapped per month ranged from 9 to 17 and the number of *P. leucopus* ranged from 10 to 14.

Sixteen species of arthropod ectoparasites were found on *M. ochrogaster* (Table 1). The greatest numbers of species were mites: *Ornithonyssus bacoti*, *Androlaelaps fahrenholzi*, *Laelaps microti*, *Radfordia lemnina*, *Dermacarus hypudaei*, *Listrophorus leukorti*, and *Mycoptes* sp. In addition to these mites, at least 2 species of chiggers were present: *Euschoengastia peromysci* and *Neotrombicula caviola*. Other arthropods present were the tick, *Dermacentor variabilis*; the louse, *Hoplopleura acanthopus* and 5 species of fleas: *Ctenophthalmus pseudagyrtes*, *Epitedia wenmanni*, *Orchopeas leucopus*, *Peromyscopsylla scotti*, and *Stenoponia americana*.

The most abundant ectoparasite on *M. ochrogaster* was the mite, *L. leukorti*, with an average number for the 13-month study period of 225.49 per animal. It was found commonly throughout the year, but was most abundant in the fall. *Dermacarus hypudaei* was also common on *M. ochrogaster* with an average of 161.0 per animal during the entire study period. However, this species was most prevalent in the spring. The mites *O. bacoti*, *A. fahrenholzi*, *L. microti*, and *Mycoptes* sp. were also encountered regularly but with decreased numbers of 23.12, 4.90, 6.31, and 1.56, respectively. *Ornithonyssus bacoti* was found most frequently in the spring, *A. fahrenholzi* was most common in the spring and summer, and *L. microti* and *Mycoptes* sp. were found most frequently in the winter and spring. *Radfordia lemnina* was encountered rarely, with an average of 0.05 per animal for the 13-month study period. It was found only in the summer and fall. Chiggers, *E. peromysci* and *N. caviola*, were found throughout the year but were most common in the winter and spring. For the entire study period, the average number of chiggers per animal was 8.33.

Ticks and lice were encountered less frequently than mites. The tick *D. variabilis* was most prevalent in the spring and there was an average of 0.21 per animal for the study period. Lice were most prevalent in the spring also, and were not found on the voles during June, July, and August. The average number of those ectoparasites for the study period was 2.62.

The occurrence of fleas was sporadic (Table 1). The highest average number for the study period was 0.32 per animal for *C. pseudagyrtes*. Numerically, the fleas were a minor component of the ectoparasitic fauna.

During the study, 16 species of arthropod ectoparasites were found on *P. leucopus* (Table 2). Of these, 14 were also present on *M. ochrogaster*, indicating a broad overlap in the ectoparasite fauna. The 14 species found on both hosts were: mites—*O. bacoti*, *A. fahrenholzi*, *L. microti*, *D. hypudaei*, *L. leukorti*, *Mycoptes* sp., and chiggers (*E. peromysci* and *N. caviola*); ticks—*D. variabilis*; and fleas—*C. pseudagyrtes*, *E. wenmanni*, *O. leucopus*, *P. scotti*, and *S. americana*. The mite *Radfordia subuliger* and the louse *Hoplopleura hespermydis* were found on *P. leucopus* but not on *M. ochrogaster*.

The most common ectoparasites of *P. leucopus* were chiggers of which at least 2 species were present. The average number of chiggers per animal throughout the study was 13.76. These arthropods were most common in the winter. The mite *D. hypudaei* was also common with an average number per animal for the study period of 4.87. It was most prevalent in the spring.

Other mites were not as prevalent. *Ornithonyssus bacoti*, *A. fahrenholzi*, *L. microti*, *R. subuliger*, *L. leukorti*, and *Mycoptes* sp.

TABLE 2.—ARTHROPOD ECTOPARASITES AND THEIR SEASONAL OCCURRENCES ON *PEROMYSCUS LEUCOPUS* IN WARREN COUNTY, KENTUCKY, FROM NOVEMBER 1970 THROUGH NOVEMBER 1971. THE NUMBERS IN PARENTHESES BELOW EACH SEASON AND THE TOTAL INDICATE THE NUMBER OF SPECIMENS EXAMINED. THERE WERE AT LEAST 2 KINDS OF CHIGGERS PRESENT.

Parasite	Average Number Per Host (minimum and maximum number per host)				
	Winter (42)	Spring (33)	Summer (37)	Fall (43)	Total (155)
Mites					
Ornithonyssus bacoti	0.18 (0–5)	2.16 (0–53)	1.72 (0–12)	0.09 (0–1)	0.82 (0–53)
Androlaelaps fahrenholzi	0.92 (0–17)	0.94 (0–5)	0.27 (0–2)	0.53 (0–6)	0.65 (0–17)
Laelaps microti	0.05 (0–1)	1.03 (0–19)	0.32 (0–9)	0.21 (0–1)	0.38 (0–19)
Radfordia subuliger	0.02 (0–1)	0	0	0.09 (0–2)	0.03 (0–2)
Dermacarus hypudaei	1.30 (0–19)	14.93 (0–424)	0.41 (0–3)	2.28 (0–30)	4.87 (0–424)
Listrophorus leukorti	0.11 (0–1)	1.81 (0–55)	0.27 (0–3)	1.90 (0–30)	1.26 (0–55)
Mycoptes sp.	0.19 (0–3)	0.09 (0–1)	0.18 (0–2)	0.37 (0–8)	0.23 (0–8)
Chiggers	26.83 (0–75)	12.60 (0–75)	2.24 (0–22)	13.04 (0–72)	13.76 (0–75)
Ticks					
Dermacentor variabilis	0.02 (0–1)	1.81 (0–12)	0.13 (0–2)	0.21 (0–3)	0.52 (0–12)
Lice					
Hoplopleura hesperomydis	2.54 (0–25)	0.63 (0–12)	0.73 (0–19)	6.21 (0–252)	2.98 (0–252)
Fleas					
Ctenophthalmus pseudagyrtes	0.04 (0–1)	0.06 (0–1)	0.16 (0–5)	0	0.06 (0–5)
Epitedia wenmanni	0.14 (0–4)	0	0.13 (0–3)	0.02 (0–1)	0.07 (0–4)
Orchopeas leucopus	0.31 (0–4)	0.03 (0–1)	0	0.02 (0–1)	0.08 (0–4)
Peromyscopsylla scotti	0	0	0	0.02 (0–1)	0.01 (0–1)
Stenoponia americana	0.28 (0–6)	0.27 (0–4)	0	0.04 (0–2)	0.15 (0–6)

had average numbers per animal of 0.82, 0.65, 0.38, 0.03, 1.26, and 0.23, respectively, for the entire study period. *Ornithonyssus bacoti* was most prevalent in the spring and summer, *A. fahrenholzi* in the winter and spring, *L. microti* in the spring, *L. leukorti* in the spring and fall, and *Mycoptes* sp. in the fall. *Radfordia subuliger* was rare and found only in the fall and winter.

Other ectoparasites also occurred in very low numbers on *P. leucopus*. *Dermacentor variabilis* occurred most frequently in the spring with an average of 0.52 per animal for the 13-month study period. The louse *H. hesperomydis* was found most frequently in the fall and winter with an average of 2.98 per animal for the study period. Fleas occurred irregularly (Table 2).

DISCUSSION

A total of 18 species of arthropod ectoparasites was found on *Microtus ochrogaster* and *Peromyscus leucopus* during the present study. Of this total, 14 species (77.7%) were common to both rodents, indicating little host specificity. Host specificity was exhibited only by mites of the genus *Radfordia* and by lice of the genus *Hoplopleura*. There was, however, a definite host preference. The ectoparasites were more numerous on *M. ochrogaster* than on *P. leucopus*. This difference in numbers possibly resulted from the heavier pelage on the voles.

The average numbers of ectoparasites obtained for *M. ochrogaster* and *P. leucopus* were higher than those reported in the literature. Whitaker and Wilson (1968), in a 3-year study of mites in Indiana, reported averages of 0, 0.19, and 0.17, respectively, for *Ornithonyssus bacoti*, *Androlaelaps fahrenholzi*, and *Laelaps microti* on *M. ochrogaster* and 0.01, 0.003, and 0.62 on *P. leucopus*, whereas our respective averages were 23.12, 4.90, and 6.31 on *M. ochrogaster* and 0.82, 0.65, and 0.38 on *P. leucopus*. Similarly, the above authors reported averages of 0.02 for *Radfordia lemnina* on *M. ochrogaster* and 0.02 for *Radfordia subuliger* on *P. leucopus*, but our findings show averages of 0.05 and 0.03, respectively. Whitaker and Wilson (1968) pointed out that their figures should be taken as minimal because of the methods used for finding mites. In our study, however, we attempted to collect and count all specimens.

Seasonal variations in numbers of parasites were observed for some ectoparasites. *Listrophorus leukorti* occurred in greater numbers in the fall on *M. ochrogaster*, but showed little seasonal variation on *P. leucopus*. On the latter species, the numbers were much lower throughout the year than on *M. ochrogaster*. *Dermacarus hypudaei* occurred on both *M. ochrogaster* and *P. leucopus* as hypopi, a second nymphal stage with specialized claspers. The adults are free living in the nests of the rodents (Drummond 1957). On both species of host, the mites were most prevalent in the spring of the year. *Ornithonyssus bacoti* showed a distinct seasonal variation on *M. ochrogaster* but not on *P. leucopus*, where it occurred in smaller numbers. The mites were most prevalent on the vole in summer. This was in contrast to the report of Worth (1950) who found maximum numbers in the spring. However, his studies were conducted in Florida where the optimum temperature for the mites would likely occur earlier.

Chiggers, *Euschoengastia peromysci* and *Neotrombicula caviola*, were common throughout the cooler months with peak numbers during the spring. There was a dramatic decrease in chiggers during the summer months. This seasonal pattern was evident both on *M. ochrogaster* and on *P. leucopus*. Chiggers are the parasitic larval stages of free living mites, and during the spring the larvae leave the host and molt to the free living stages. This type of incidence pattern has been described by Farrell (1956).

Dermacentor variabilis occurred as immature stages, larvae and nymphs, on both hosts. These immature stages were most prevalent during the spring, and this observation follows the life cycle pattern reported by Smith et al. (1946) who found that the activity of the immature forms reached a peak during March, April, and May, after which these forms became rare or absent.

The lice, *Hoplopleura acanthopus* on *M. ochrogaster* and *Hoplopleura hesperomydis* on *P. leucopus*, showed a distinct seasonal variation. *Hoplopleura acanthopus* was most prevalent in the spring and *H. hesperomydis* was most prevalent in the fall. These results are similar to those reported by Cook and Beer (1958) for *H. acanthopus* on *Microtus pennsylvanicus* and *H. hesperomydis* on *Peromyscus maniculatus*. Batson (1965) found *H. acanthopus* to be the most abundant ectoparasite of *M. ochrogaster* in central Kentucky but this was not the case in the present study.

Insufficient numbers of each of the 5 species of fleas were taken to accurately

depict their seasonal incidence. This is true also of many of the mites found during our study. The interpretation of the effects of season upon the numbers of some of the species of ectoparasites present on the hosts is severely limited by the low numbers present. In some instances, an abundance of individuals upon a single host dramatically increased the average number of the parasite for that season. Such occurrences adversely affect the interpretation of the data. Such effects could be overcome by collecting larger numbers of rodents over several years.

LITERATURE CITED

BATSON, J. 1965. Studies on the prairie vole, *Microtus ochrogaster*, in central Kentucky. Trans. Ky. Acad. Sci. 25:129–137.

COLEMAN, R. W. 1950. DDT protects baits from ants. J. Mamm. 31:199.

COOK, E. F., AND J. R. BEER. 1958. A study of louse populations on the meadow vole and deer mouse. Ecology 39:645–659.

DRUMMOND, R. O. 1957. Observations on fluctuations of acarine populations from nests of *Peromyscus leucopus*. Ecol. Monogr. 27:137–152.

FARRELL, C. E. 1956. Chiggers of the genus *Euschoengastia* (Acarina: Trombiculidae) in North America. Proc. U.S. Natl. Mus. 106: 85–235.

JAMESON, E. W., JR. 1947. Natural history of the prairie vole. Univ. Kans. Publ. Mus. Nat. Hist. 1:125–151.

SMITH, C. N., M. M. COLE, AND H. K. GOUCK. 1946. Biology and control of the American dog tick. U.S. Dept. Agric. Tech. Bull. 905: 1–74.

VERTS, B. J. 1961. Observations on the fleas (Siphonaptera) of some small mammals in northwestern Illinois. Amer. Midl. Nat. 66: 471–476.

WHITAKER, J. O., JR. 1968. Parasites. In Biology of *Peromyscus* (Rodentia) Spec. Publ. Amer. Soc. Mamm. 2:254–311.

———, AND N. WILSON. 1968. Mites of small mammals of Vigo County, Indiana. Amer. Midl. Nat. 80:537–542.

WORTH, C. B. 1950. Observations on ectoparasites of some small mammals in Everglades National Park and Hillsborough County, Florida. J. Parasit. 36:326–335.

An Examination of Opossums and Raccoons in Kentucky for Natural Infections with *Trypanosoma cruzi*

Fred H. Whittaker and Lena Jarecka
Department of Biology, University of Louisville, Louisville, Kentucky 40208

Abstract

Fifty-nine raccoons and 24 opossums were live-trapped from 14 counties in Kentucky and examined for the presence of *Trypansoma cruzi*, the causative agent of Chagas' disease. Although none of the mammals was infected with *T. cruzi*, reasons are stated as to why it is believed that with the examination of additional mammals, the parasite will be found in Kentucky.

Introduction

Trypanosoma cruzi, the causative agent of American trypanosomiasis, was first described by Carlos Chagas in 1909 from infected triatomid bugs, wild mammals, and humans in Brazil. In honor of his achievement, this disease is usually referred to as Chagas' disease. Later studies (Olivier et al. 1972) showed this organism to be present and pathogenic for humans in most areas of South and Central America. Early work in this country (Kofoid and McCulloch 1916, Wood 1934, Wood and Wood 1941) indicated that the organism was present in triatomids and various reservoir hosts in much of the Southwest. Woody and Woody (1955) reported the first indigenous human infection in a child from Corpus Christi, Texas, which was soon followed by a similar case in Bryan, Texas (Gobel 1958). Later work in Louisiana (Yaeger 1960), in Maryland (Walton et al. 1958, Herman and Bruce 1962), in Georgia and Florida (McKeever et al. 1958) and in Alabama (Olsen et al. 1964) has extended the known range of this organism into 10 states. Farrar et al. (1963) found definite serological evidence of infected humans in certain regions of Georgia, and postulated that at least one death in the region was caused by *T. cruzi*. These findings suggest that *T. cruzi* may constitute a potential human health problem in this country.

Because of the scanty knowledge of this organism's distribution in the United States, it is seldom considered in the differential diagnosis of a disease. A more thorough knowledge of the distribution of *T. cruzi* would, in all probability, stimulate the medical profession to consider the potential for human infection with this disease. With early diagnosis, the chances for a complete recovery are excellent, but a satisfactory cure for chronic Chagas' disease has not been developed.

Triatomid vectors and a wide range of known mammalian hosts (such as opossums, raccoons, various species of rats and mice, and gray foxes) are found in Kentucky. There are no major geographic or environmental barriers which would prevent *T. cruzi* from entering this state, and based on the knowledge of zoodistribution, there is no reason to assume that it should not be found in Kentucky. It should be mentioned that an earlier examination of 41 opossums from central Kentucky by Aliff (1970) was negative for *T. cruzi*.

When one considers the close proximity certain reservoir hosts maintain with humans, as well as the fact that triatomids are often pests in human habitations where poor living conditions and health standards prevail, the need for this research project appeared to be warranted. This report represents the results of an examination of raccoons and opossums in 14 counties of Kentucky for the presence of Chagas' disease caused by *T. cruzi*.

Results

From January to May 1972, 59 raccoons and 24 opossums were live-trapped from 14 counties in Kentucky (Table 1).

The animals were brought to the laboratory at the University of Louisville and maintained in cages until necropsied. Each animal was anesthetized with sodium pentobarbital, 150 mg/kg intraperitoneally, and a 3-ml blood sample obtained by cardiac puncture. The sample was citrated and added to a screw-top test tube containing 7 ml of a culture medium developed by Nakamura (1967).

The thoracic cavity was opened and a small portion of cardiac muscle excised and placed in a tube of Nakamura's medium. The abdominal cavity was then opened and a small section of kidney tissue excised and placed into another tube of the same medium. To each of the culture tubes were added 500 units of penicillin G and 1.5 μg of streptomycin sulfate per milliliter.

All tubes of inoculated media were incubated at 24–25 C for 2 weeks before the first examination for trypanosomes. In each case, an uninoculated tube of medium served as a control. Each tube was examined weekly thereafter for 6 weeks.

Throughout the period of examination, all culture tubes were negative for any stage of *T. cruzi*. This suggests absence or rarity of the parasite in those regions of the counties from which the animals were collected. We hesitate to say unequivocally that *T. cruzi* does not occur in Kentucky. More animals should be examined before any definite conclusions can be reached. Furthermore, the physical and biotic conditions of Kentucky are sufficiently similar to those of some of the other states (New Jersey, Maryland, Alabama, and Georgia) in which *T. cruzi* has been found. Probably, there are no real barriers to prevent a more northward extension of the parasite's range, provided that among other things the reservoir hosts (raccoons, opossums, etc.) and triatomid insect vector are present.

According to Kagan et al. (1966), the northern range of *T. cruzi* would be delimited by the range of the insect vector *Triatoma sanguisuga*. This latter range describes an arc passing from eastern New Mexico northeastwardly through several states, including Illinois, Indiana, Ohio, and Pennsylvania. This would thus include Kentucky as a potential site for the parasite. It is undoubtedly only a matter of time, and the examination of additional animals before *T. cruzi* is found in Kentucky.

Table 1.—Number of Raccoons and Opossums Collected From Each County

County	Number of Opossums	Number of Raccoons
Allen	1	4
Bell		3
Bullitt	3	5
Christian	2	1
Graves	1	6
Jefferson	3	8
Lyon		1
McCreary		4
Oldham	4	7
Powell		6
Russell	1	5
Trimble	4	2
Warren	2	2
Whitley	3	5
Totals	24	59

We want to extend our sincere thanks to the Kentucky State Department of Health (Frankfort), the Arts and Sciences Research Committee of the University of Louisville, and Dr. George Brodschi, Director, International Center, for financing this project.

Literature Cited

Aliff, J. V. 1970. A search for *Trypanosoma cruzi* in Kentucky opossums. Trans. Ky. Acad. Sci. 31:104.

Chagas, C. 1909. Trabalho do instituto de manguinhos sobre uma nova trypanosomiase humana. Ann. Acad. Med. Rio de Janeiro. 75:188–190.

Farrar, W. E., I. G. Kagan, F. D. Everton, and T. G. Sellers. 1963. Serologic evidence of human infection with *Trypanosoma cruzi* in Georgia. Amer. J. Hyg. 78:166–172.

Gobel, F. C. 1958. A comparison of strains of *Trypanosoma cruzi* indigenous to the United States with certain strains from South America. Proc. 6th Internatl. Cong. Trop. Med. Malar. 3:158–166.

Herman, C. M., and J. I. Bruce. 1962. Occurrence of *Trypanosoma cruzi* in Maryland. Proc. Helminth. Soc. Wash. 29:55–58.

Kagan, I. G., L. Norman, and D. Allain. 1966. Studies on *Trypanosoma cruzi* isolated in the United States: A review. Rev. Biol. Trop. 14:57–73.

KOFOID, C. A., AND I. MCCULLOCH. 1916. On *Trypanosoma triatomae*, a new flagellate from a hemipteran bug from the nests of the wood rat, *Neotoma fuscipes*. Univ. Calif. Publ. Zool. 16:113–126.

MCKEEVER, S., G. W. GORMAN, AND L. NORMAN. 1958. Occurrence of a *Trypanosoma cruzi*-like organism in some mammals from southwestern Georgia and northwestern Florida. J. Parasit. 44:583–587.

NAKAMURA, M. 1967. An autoclaved medium for routine cultivation of *Trypanosoma cruzi*. Trans. Roy. Soc. Trop. Med. Hyg. 61:792–794.

OLIVIER, M., L. OLIVIER, AND D. SEGAL. 1972. A bibliography on Chagas' disease (1909–1969). Special Publication No. 2, Index Catalog of Medical and Veterinary Zoology. U.S. Gov. Print. Off., Wash., D.C., 633 pp.

OLSEN, F. P., J. P. SHOEMAKER, H. F. TURNER, AND K. L. HAYS. 1964. Incidence of *Trypanosoma cruzi* (Chagas) in wild vectors and reservoirs in east-central Alabama. J. Parasit. 50:599–603.

WALTON, B. C., P. M. BAUMAN, L. S. DIAMOND, AND C. M. HERMAN. 1958. The isolation and identification of *Trypanosoma cruzi* from raccoons in Maryland. Amer. J. Trop. Med. Hyg. 7:603–610.

WOOD, E. D., AND S. F. WOOD. 1941. Present knowledge of the distribution of *Trypanosoma cruzi* in reservoir animals and vectors. Amer. J. Trop. Med. 21:335–345.

WOOD, F. D. 1934. Natural and experimental infection of *Triatoma protracta* Uhler and mammals in California with American human *Trypanosomiasis*. Amer. J. Trop. Med. 14: 497–511.

WOODY, N. C., AND H. B. WOODY. 1955. American Trypanosomiasis (Chagas' Disease) First indigenous case in the United States. J. Amer. Med. Ass. 159:676–677.

YAEGER, R. G. 1960. A method of isolating trypanosomes from blood. J. Parasit. 46:288.

Distribution and Life History Notes on the Southeastern Five-Lined Skink, *Eumeces inexpectatus* Taylor, in Kentucky

ERIC M. RUNDQUIST AND JOSEPH T. COLLINS
Museum of Natural History, University of Kansas, Lawrence, Kansas 66045

Barbour and Ernst (1971) defined the range of *Eumeces inexpectatus* in Kentucky on the basis of records or literature reports from Barren, Bell, McCreary, Powell, and Whitley counties, mostly in the southeastern part of the state. With the exception of the Barren County specimen, these records are restricted to or along the edge of the mountainous, heavily forested area of eastern Kentucky. Excepting the Barren County record, this lizard has not been known from western Kentucky, but Barbour (1971) speculated that it might be found as far west in the state as Todd County. Snyder (1972) did not find *Eumeces inexpectatus* in the Land Between The Lakes (LBL) in Trigg and Lyon counties, southwestern Kentucky, but indicated (p. 84) that there was a "moderate possibility" of its occurrence in that area.

Recent field work in the LBL region and reexamination of specimens of *Eumeces* in the herpetological collection of the Museum of Natural History at the University of Kansas (KU) have resulted in the discovery of specimens of *Eumeces inexpectatus* from new localities in western and southwestern Kentucky.

During May 1973 one of us (EMR) and Walter E. Boles spent 10 days collecting amphibians and reptiles in southwestern and west-central Kentucky. Six examples of *Eumeces inexpectatus* were collected at the following Kentucky localities: EDMONSON COUNTY: W Horse cave near border Mammoth Cave National Park (KU 154079); TRIGG COUNTY: ca. 7 mi (11 km) ESE Aurora in LBL (KU 154077–078 & KU 154080); ca. 10 mi (16 km) ESE Aurora in LBL (KU 154081–082). In addition, 9 previously overlooked specimens of this lizard were discovered from the following Kentucky localities: HART COUNTY: 6–7 mi (10–11 km) NW Cave City near border Mammoth Cave National Park (KU 143707–708); LYON COUNTY: 7 mi (11 km) N Lyon-Trigg county line on Ky. Hwy. 453 (KU 137757); MCCREARY COUNTY: 6.4 mi (10.3 km) WNW Stearns on Ky. Hwy. 92 (KU 143705–706), 0.7 mi (1.1 km) W Cumberland Falls (KU 144580), no other locality data (KU 144581); TRIGG COUNTY: 0.5 mi (0.8 km) NE jct. eastern shore Kentucky Lake and U.S. Hwy. 68 in LBL (KU 144576–577). The specimens from Edmonson, Hart, and McCreary counties supplement the records of Ernst and Barbour (1971), and those from Lyon and Trigg counties extend the range of *Eumeces inexpectatus* ca. 130 miles (210 km) (airline) west into southwestern Kentucky (Fig. 1).

Virtually nothing is known of the life history in Kentucky of *Eumeces inexpectatus* and its relationships with *Eumeces fasciatus*, a more wide ranging and (evidently) more abundant species with which it is sympatric over large areas.

Only 3 female Kentucky *Eumeces inexpectatus* (KU 137757, 143707, 144581) were available for examination. These specimens contained an average of 11 undeveloped ova. This differs little from the ova counts obtained from 4 female *Eumeces fasciatus* taken in sympatry with *Eumeces inexpectatus* in Kentucky, although our sample size is too small to be conclusive.

Analysis of stomach contents of 12 *E. inexpectatus* and 13 *E. fasciatus* from their area of sympatry in Kentucky showed no appreciable difference in the diet of these species. Both species consumed large numbers of spiders compared to other invertebrate diet items which included (in descending order of item occurrence) crickets, cockroaches, caterpillars, grasshoppers, ants, beetle larvae, snails, and moths.

Although our data sample is small, these

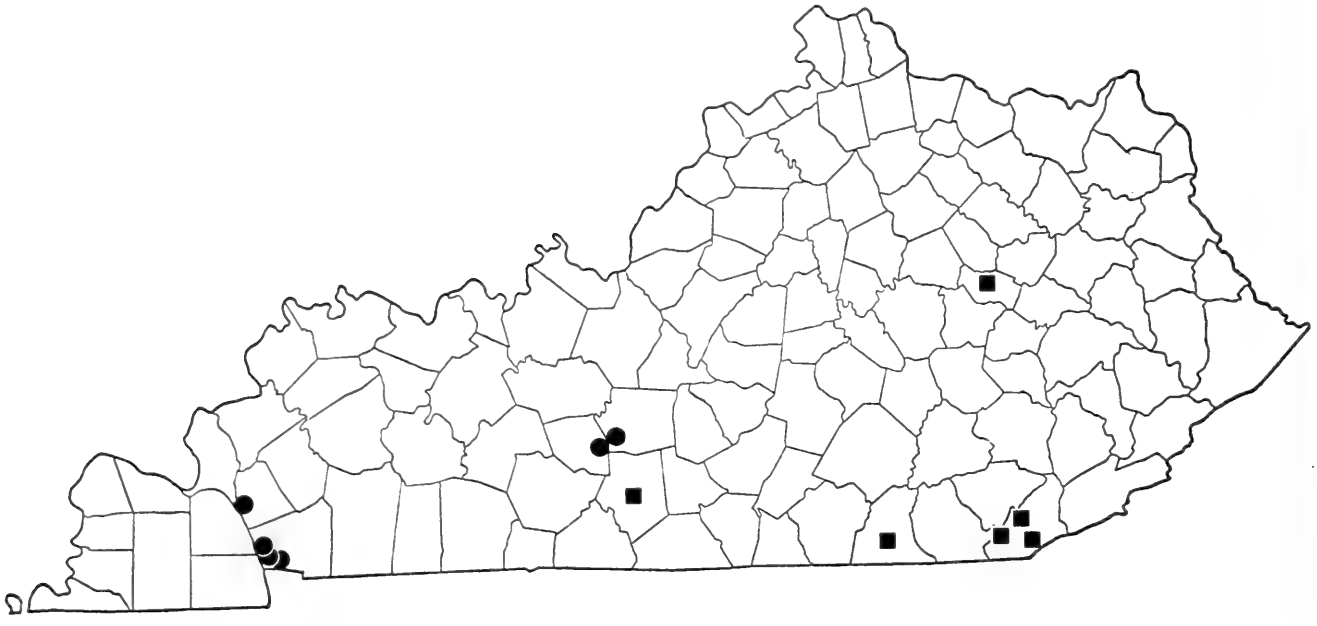

FIG. 1. Known localities from which *Eumeces inexpectatus* has been collected in Kentucky. The solid squares represent records reported by Barbour and Ernst (1971). The solid circles are new localities based on specimens reported in this paper.

observations tentatively indicate little difference in reproductive potential or diet in these 2 lizards. More specimens and, particularly, associated microhabitat data are needed to determine what, if any, nonmorphological differences separate Kentucky *Eumeces inexpectatus* and *Eumeces fasciatus* in areas of sympatry.

We wish to thank Walter E. Boles and George R. Pisani for their assistance during field work in Kentucky. George W. Byers of the Department of Entomology, University of Kansas, identified insect remains from the stomachs of lizards cited here. To him we are most grateful. Field work was supported by the Museum of Natural History, University of Kansas and the Kentucky Academy of Science (J. T. Collins, principal investigator).

LITERATURE CITED

BARBOUR, R. W. 1971. Amphibians and reptiles of Kentucky. Univ. Press Kentucky, Lexington, Ky. 334 pp.

BARBOUR, R. W., AND C. H. ERNST. 1971. The distribution of *Eumeces* in Kentucky. J. Herp. 5(1–2):71–72.

SNYDER, D. H. 1972. Amphibians and reptiles of Land Between the Lakes. TVA Publ. 90 pp.

Additional Observations on the Effects of Strip Mining on Small-Stream Fishes in East-Central Kentucky[1]

Branley A. Branson and Donald L. Batch
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Continued siltation from strip mine operations in 2 streams tributary to the North Fork of the Kentucky River has prevented the recovery of fish populations in those streams. All species reported from Leatherwood Creek in 1972 have been forced downstream, and 6 of those species are now absent from that stream. Two other species are now missing from both streams. Populations of *Semotilus atromaculatus* apparently are on the increase, perhaps because of the removal of competing species.

Introduction

This report continues the observations on the effects of siltation from strip mines on the fish life of 2 small streams in east-central Kentucky commenced in an earlier paper (Branson and Batch 1972). That work covered a 17-month period (May 1967 through September 1969), whereas the present contribution extends from November 1971 through December 1972.

Our study area, in Breathitt County, includes Leatherwood Creek (5.63 km long), tributary to Quicksand Creek, and Bear Branch (3.22 km long), tributary to Buckhorn Creek, all segments of the North Fork of the Kentucky River. These streams were originally selected because strip mine spoil banks in the area are very low in acid-producing substances, making them admirable for the purpose of studying silt effects (Branson and Batch 1972). Both study streams comprise order I and II tributaries. Six stations, equally distributed from headwaters to mouth, were established on each stream. Detailed information on the bottom conditions and water quality were presented in the previous study. During each visit to these stations fish were collected by 30 min of intensive seining, and were then identified and released (Table 1).

Weekly determinations of turbidity are here presented as averages and monthly ranges (Fig. 1, Table 2). There were, of course, as previously observed by us (loc. cit.), corresponding fluctuations in sediment loads and sulfate (SO_4) concentrations, varying with peak flow values. Sulfate loads are never very high in either stream during any season of the year, but they are high enough to permit utilization for the purpose of indexing surface disturbance. It is apparent from the graph and the data in Table 1 that the silt load in Bear Branch, during the study period, was in the main higher than that in Leatherwood Creek. Mining operations commenced in the Leatherwood drainage 15 August 1967, ceased temporarily on 17 December 1968, then resumed for several months in late 1970. During the latter period, a rather massive silt retention dam (92 m long and 12–15 m deep) was constructed across the flow channel below our Station 3, completely eliminating the upper 3 collecting sites and effectively eliminating the headwaters of the stream. The rejuvenated mining operation, plus the construction disturbance of dam building, dumped tons of silt into Leatherwood Creek, reducing by narrowing of the flow channel and by bottom filling the main channel by 60 to 75 percent, from midway in the stream to its mouth.

In Bear Branch, mining started in mid-August 1969, and it was still in progress in August 1973. By September 1972 our Station 4 had become completely obliterated by silt, including vast quantities of

[1] Conducted in cooperation with the Northeastern Forest Experiment Station, U.S. Forest Service, Berea, Kentucky.

TABLE 1.—COMPARISON OF FISH FAUNAS AT 6 SITES EACH IN LEATHERWOOD AND BEAR BRANCH CREEKS, BREATHITT COUNTY, KENTUCKY. UPPER ROW OF SYMBOLS, FOR EACH SPECIES, LEATHERWOOD SAMPLES; LOWER ROW, BEAR BRANCH. VISITATION DATES FOR LEATHERWOOD CREEK: 3 OCTOBER 1971, 14 AUGUST 1971, AND 12 DECEMBER 1972; AND 7 NOVEMBER 1970, 4 SEPTEMBER 1971, AND 9 SEPTEMBER 1972 FOR BEAR BRANCH. + INDICATES PRESENCE; – INDICATES ABSENCE.

Species	Collecting Stations					
	1	2	3	4	5	6
Semotilus atromaculatus	--- +++	--- +++	+-- +++	+++ +--	+++ +++	+++ +++
Campostoma anomalum	--- ---	--- ---	--- ++-	+++ ---	+++ ++-	+++ +-+
Ericymba buccata	--- ---	--- ---	--- ++-	+-+ ---	+++ ++-	+++ +--
Notropis ardens	--- ---	--- ---	--- ---	--- ---	--- ---	-+- +--
Notropis chrysocephalus	--- ---	--- ---	--- ---	--- ---	--+ ---	-++ +-+
Notropis photogenis	--- ---	--- ---	--- ---	--- ---	--- ---	--- --+
Notropis volucellus	--- ---	--- ---	--- ---	--- ---	--- ---	-+- +--
Pimephales notatus	--- ---	--- ---	--- ++-	--- ---	--- ++-	+++ +++
Nocomis micropogon	--- ---	--- ---	--- ---	--- ---	--- ++-	--- +++
Hypentelium nigricans	--- ---	--- ---	--- ---	--- ---	--- ---	--- ---
Percina maculatum	--- ---	--- ---	--- +--	--- ---	--- ---	--- ---
Etheostoma flabellare	--- ---	--- ---	--- ---	--+ +--	+-+ +++	--+ +++
Etheostoma caeruleum	--- ---	--- ---	--- ---	--- ---	--- ++-	+++ +++
Etheostoma nigrum	--- ---	--- ---	--- ---	--- ---	--- ++-	--- +++
Etheostoma variatum	--- ---	--- ---	--- +--	--- ---	--- ---	--- +++
Etheostoma saggita	--- ---	--- ---	--- ---	--- ---	-+- ++-	--- --+
Etheostoma blennioides	--- ---	--- ---	--- ---	--- ---	--- ---	--- ++-
Etheostoma species	--- ---	--- ---	--- ---	--- ---	--- ---	--- +++

large gravel and rocks up to boulder size. Previous accounts of siltation in these 2 drainages were reported by us in 1972.

RESULTS AND DISCUSSION

Comparison of the results presented in Table 1 [in which a minus sign (–) indicates the absence of a species and a plus sign (+) indicates its presence] with those obtained during the first study (loc. cit.) demonstrates not only that the fish fauna of the 2 streams has not been able to recover to any extent, but also that some species have been eliminated from the fauna. *Notropis photogenis*, *Nocomis micropogon*, *Etheostoma nigrum*, *E. variatum*, *E. blennioides*, and the emerald darter (*Etheostoma* sp.) are now missing from the Leatherwood Creek fauna, and *Hypentelium nigricans* and *Percina maculata* are absent from both streams. Furthermore, with the exception of the creek chub, *Semotilus atromaculatus*, all species have been forced downstream until only nominal populations are present in short stretches above the mouth. In Leatherwood Creek, this is a particularly sad commentary, since Quicksand Creek itself is heavily afflicted with silt, and hence shall be unable to act as an efficient reservoir from which fishes may reinvade Leatherwood Creek.

Populations of *Semotilus atromaculatus*,

TABLE 2.—HIGH AND LOW TURBIDITY READINGS (JACKSON TURBIDITY UNITS) IN LEATHERWOOD AND BEAR BRANCH CREEKS, BREATHITT COUNTY, KENTUCKY, BASED UPON WEEKLY DETERMINATIONS DURING THE STUDY PERIOD

Month	Leatherwood Creek	Bear Branch
November 1971	16–20	22–310
December 1971	26–97	26–61
January 1972	290–880	282–2156
February 1972	64–184	1024
March 1972	26–95	222–5300
April 1972	8–233	32–168
May 1972	65–140	51–193
June 1972	4–860	8–128
July 1972	4–12	12–629
August 1972	20–30	12–39
September 1972	20–39	20–47
October 1972	8–36	16–375

however, following abatement of active siltation, appear to be increasing, particularly at downstream sites. In our judgement, this reflects the removal of competing fish species, but it is a problem which should be studied in more detail for verification.

We thank Messrs. Frank Howard and Bruce Bauer for field assistance, and particularly Mr. Willie Curtiss, U.S. Forestry Service, for providing us with weekly water quality determinations.

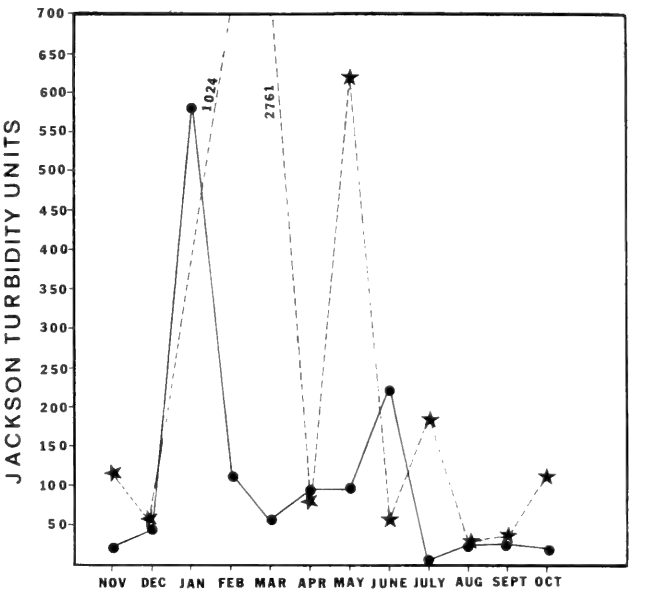

FIG. 1. Turbidity (Jackson Turbidity Units) in Leatherwood (filled circles, solid line) and Bear Branch (filled stars, broken line) creeks during the last 2 months of 1971 and the first 10 months of 1972. Averages of 4 or 5 samples (1 per week) according to the number of weeks per month. (See text for additional discussion.)

LITERATURE CITED

BRANSON, B. A., AND D. L. BATCH. 1972. Effects of strip mining on small-stream fishes in east-central Kentucky. Proc. Biol. Soc. Wash. 84:507–517.

NEWS AND COMMENT

Floristic Survey Grant of the KAS Through the generosity of an anonymous donor, the KENTUCKY ACADEMY OF SCIENCE is authorized periodically to award a cash grant of $500.00 to any student who is a member of the KENTUCKY ACADEMY OF SCIENCE and who is enrolled in a course of study with emphasis in botanical science at any college or university within the Commonwealth. The recipient of the grant would be expected to utilize the funds in support of research to survey and document the flora of any county in the state that has not had a published county flora within the last 50 years. The following requirements and/or restrictions must be met by the grantee:

1. The floristic survey of the county chosen must be under the supervision of a qualified biologist of one of the colleges or universities in Kentucky. The supervisor of such work would not necessarily have to be from the same college or university as the student chosen for the grant.
2. As a general rule it would be expected that a minimum of 500 different vascular plant species would be collected. Prepared specimens of each species would be made in minimums of three with an average of five, recognizing on occasion only one or two specimens might be available. For each species collected over 500, an additional $1.00 will be made available at the end of the grant period by the donor.
3. To ensure documentation of the flora for future reference, and in order to build and stimulate botanical interest regionally, the deposition of correctly prepared specimens is to be made at a national herbarium with an identical group deposited in a working herbarium of the Regional Colleges and Universities of Kentucky. The selection of both a national herbarium and regional site of deposition is to be made by the Floristic Survey Grant Committee.
4. Upon completion of the work (a period not to exceed 24 months from date of grant receipt) a written summary of the project including a complete listing of the county's flora in a conventional format will be submitted to the Floristic Survey Grant Committee.
5. The choice of the student to receive this grant will be at the discretion of the Floristic Survey Grant Committee to be composed of the following individuals. The person in charge of this committee will be designated from the following by the President of the Kentucky Academy of Science.
    a. Chairman (or his designate) of the Department of Biology at Western Kentucky University.
    b. Chairman (or his designate) of the Department of Biology at Murray State University.
    c. A Biologist from any other college or university in Kentucky to be appointed by the President of the Kentucky Academy of Science.
6. The funds provided by this grant are to be utilized to defray travel costs and costs of materials and supplies needed to undertake and complete the work. The grantee will be required to obtain and maintain a separate checking account in his/her name with the funds from this grant and to provide proper records of expenditures annually to the Floristic Survey Grant Committee. Any excess funds at the end of the 24-month period will be returned by check to the Treasurer of the Kentucky Academy of Science for inclusion in the next Floristic Survey Grant. If for any reason continuing funding for the Floristic Survey Grant would be terminated, any excess funds would be added to the general revenue of the Kentucky Academy of Science.

ACADEMY AFFAIRS

The Sixtieth Annual Business Meeting of the Kentucky Academy of Science, Centre College of Kentucky, Danville, Kentucky

1 and 2 November 1974

Host: Dr. Frederick M. Brown, Professor of Psychology

Minutes of the Annual Business Meeting

The meeting was called to order by President Donald Batch at 8:15 A.M., 2 November, in Room 101, Young Hall. About 65 members were in attendance.

As the first item of business, the motion by Secretary Prins and second by W. Martin, to approve the Minutes of the 59th annual business meeting at Transylvania University, carried. Secretary Prins then announced that membership to date stood at about 516 regular members and 30 institutional subscribers. W. J. Meijer moved that the 66 new members be formally accepted into the Academy. H. Powell second the motion and it carried. Secretary Prins then read the names of the following deceased members: E. B. Penrod, R. C. Jett, W. Blackburn, and Anna Hoffman. Both Drs. Penrod and Blackburn played active roles in the Academy affairs, including serving terms as President of the K.A.S. President Batch requested a moment of tribute to the deceased members.

The Treasurer's report was distributed to the members present which was certified as accurate by the audit committee consisting of Drs. W. H. Strobe, E. E. Hegen, and E. O. Beal (Chm). The committee also commended the Treasurer Hoffman for maintaining excellent records.

Treasurer's Report to the Audit Committee, Kentucky Academy of Science, for the period 1 October 1973–8 October 1974.

Cash in Citizens National Bank Bowilng Green, Kentucky		$1,378.67
RECEIPTS:		
Subsidy from State	$3,000.00	
Membership Dues	1,581.00	
Reprints	194.50	
Annual Meeting	766.50	
Transactions Subscriptions	214.50	
University of Louisville Purchase of Transactions	300.00	
AAAS Research Grant	128.00	
Miscellaneous (Private Gift)	80.00	6,264.50
		$7,643.17
DISBURSEMENTS:		
Research Grants	$ 200.00	
Annual Meeting	476.92	
Publication of Transactions	3,757.61	
AAAS Dues	23.75	
Stationery, Printing	115.84	
KJAS	300.00	
Miscellaneous	30.54	4,904.66
		$2,738.51
Check Outstanding KJAS	$ 300.00	
Cash in Citizens National Bank		$2,738.51 (a)
Savings Account—Lexington Federal Savings & Loan		1,147.00 (b)
Thomas Hunt Morgan Fund		176.61[1]
TOTAL ASSETS		4,062.12

R. Prins moved and F. Toman seconded the motion to approve the Audit Committee's and Treasurer's reports. Motion carried.

Dr. Batch then turned to the business of the Standing Committees. The committees that had reports distributed copies in writing to the membership present to facilitate action on them.

1. **Committee on Membership.** No report.

2. **Committee on Publications.** The written report of Dr. Krumholz (Editor) essentially stated that the 1975 issues of the Transactions will be distributed in April and October and that members of all disciplines are urged to submit papers. H. Powell moved and F. Six seconded the motion to approve the report. Motion carried.

3. **Committee on Legislation.** The primary work of the Committee in 1974 was directed toward follow-up of the Task Force on Scientific Manpower and Needs in Kentucky. Dr. T. George moved to accept the report. Dr. E. Brown seconded the motion. Motion carried.

4. **Committee on Distribution of Research Funds.** The Committee, chaired by H. Powell, announced that Mr. Steven Zeil of Thomas More College was being recommended to receive the total $124.00 for a research proposal entitled: "Birefringence in Piezoelectric Crystals." The Committee also recommended that recipients henceforth submit progress reports to the Committee upon completion of the project or by the next annual meeting, whichever comes first. S. Jones moved and T. Coohill seconded the motion to adopt both the recommendations of the committee. Motion carried. There were only six applicants for the grant this year.

After disposing of the Standing Committee reports, Dr. Batch then asked for consideration of

[1] Account cancelled.

other reports, copies of which were submitted to the membership present.

1. **The Junior Academy.** Dr. Wm. Martin summarized the 1974 activities of the KJAS, and announced that regional meetings were going to be held at seven institutions in Kentucky this fall. He also announced the appointment of Dr. Truman Stevens (University of Kentucky) to the Governing Committee of the Junior Academy, joining H. Leopold (WKU). Dr. Batch announced that the Junior Academy books had been audited and found to be in order. After a motion and second by G. Wilson and H. Powell, respectively, the report was accepted. Dr. Batch then announced that the Executive Committee had accepted Dr. Martin's letter of resignation as Director of the Junior Academy, effective in the Spring of 1975, after a replacement is named. A tribute of appreciation was extended to Dr. Martin for doing a fine job.

2. There were no reports from the AAAS representatives.

3. **The Board of Directors** was very active in 1974. Dr. C. Kupchella (Chm), distributed a lengthy report which proposed possible activities for the Board and constitutional changes to clarify the intended role of the board. The Executive Committee will consider the suggestions at a subsequent meeting. A motion to accept the report (W. Martin), duly seconded by L. A. Krumholz, carried.

4. **The Teachers Certification Committee,** T. George (Chm), finished its work in 1974, and submitted a lengthy report on "Recommendations for Teacher Certification." This report has been submitted to the State Committee on Teacher Certification and will be defended by representatives of the K.A.S. committee this fall. Dr. Batch commended Dr. George and his committee whereupon the report was accepted after a motion and second by C. Kupchella and L. A. Krumholz, respectively.

There was no old business to come before the Academy.

Under new business, President Batch announced that the Executive Committee had accepted a proposal to establish a grant for Floristic Studies in the Commonwealth of Kentucky. This grant of approximately $600.00 will be entirely funded by an anonymous donor. Details about the grant will be announced elsewhere (see News and Comment). The membership endorsed the action of the Executive Committee through a motion by W. Martin and a second by C. Covell.

The following Resolution was accepted through a motion and second by H. Powell and L. Elliott, respectively:

RESOLUTION

The Kentucky Academy of Science takes this opportunity to recognize the outstanding role of Centre College in furthering higher education and, in particular, the sciences.

Recognition is made of the following as representative of an illustrious history:

1. In 1819, Presbyterian leaders decided to organize a new college and Isaac Shelby was the first chairman of the Board.
2. Centre College of Kentucky opened in fall 1820, and about ten years later natural sciences were added to the curriculum.
3. Centre College's alumni have made very noteworthy contributions. Among the alumni have been ten Vice-Presidents of the United States, one Chief Justice of the United States, one Associate Justice of the Supreme Court, and thirteen United States Senators.
4. In more recent years, Centre College's excellent faculty and alumni have made noteworthy contributions.

The Kentucky Academy of Science recognizes Centre College's long and illustrious history and its viable and significant role today.

Be it resolved that the Kentucky Academy of Science expresses its most sincere appreciation to Centre College for the opportunity to convene on its fine campus and for the gracious hospitality it has extended during this 1974 Annual Session.

The slate of officers for 1975 was submitted by the nominations committee, M. Taylor, Chairman, as follows:

President: Ellis V. Brown, University of Kentucky
President Elect: Frederick M. Brown, Centre College
Vice President: Charles Payne, Morehead State University
Secretary: Rudolph Prins, Western Kentucky University
Treasurer: Wayne Hoffman, Western Kentucky University
AAAS Representatives: Branley Branson, 1974–1975
John Carpenter, 1974–1977
Board of Directors: Howard Powell, Eastern Kentucky University (finish the term for Charles Payne)
John G. Spanyer, Brown Forman Distilleries, 1978
Oliver Zandona, Ashland Oil and Refineries, 1978

Dr. Batch opened the floor to additional nominations. Hearing none, W. Wagner moved that nominations close and that the slate be accepted by acclamation. R. Martin seconded the motion which carried unanimously. The President then ordered the Secretary to declare the nominees elected by acclamation.

President Batch then announced that an invitation from the University of Louisville Health Science Center to hold the 61st Annual Meeting of

the Academy there was accepted by the Executive Committee.

Dr. C. Covell expressed satisfaction and gratification to outgoing officers. This was endorsed by applause from the members present.

President Batch then introduced the new President of the Academy, Dr. Ellis V. Brown of the University of Kentucky who, in turn, expressed thanks to Dr. Batch for the work he did in 1974.

There being no further business, G. Wilson moved to adjourn. The motion carried after a second by H. Powell. The Sixtieth Annual Business Meeting of the Kentucky Academy of Science adjourned at 9:10 A.M.

Rudolph Prins, Secretary
Kentucky Academy of Science

PROGRAM

Friday, 1 November

1:00–7:00 PM REGISTRATION: Foyer, Regional Arts Center

1:00 SECTIONAL MEETINGS

3:30 STANDING COMMITTEE MEETINGS
- Membership: Room 402 Grant Hall
- Legislation: Foyer of Regional Arts Center
- Distribution of AAAS Funds: Room 101 Grant Hall
- Publications: Room 156 Young Hall
- Resolutions: Room 154 Young Hall
- Nominations: Room 152 Young Hall
- Board of Directors: Room 101 Young Hall

4:30 EXECUTIVE COMMITTEE & SECTIONAL CHAIRPERSONS: Isaac Shelby Room Regional Arts Center

7:30 BANQUET: Cowan Dining Commons
- Presiding: Dr. Donald Batch, President, Kentucky Academy of Science
- Speaker: Dr. George Sands, Langley Research Center, National Aeronautic and Space Administration

Saturday, 2 November

8:00–9:00 AM REGISTRATION: Lobby, Young Hall

8:00–9:00 CAFETERIA CONTINENTAL BREAKFAST: Venetian Room, Cowan Dining Commons

8:00–9:30 60th ANNUAL BUSINESS MEETING: Auditorium, Room 101 Young Hall

9:30–10:30 GENERAL SESSION: "Research in Kentucky" Auditorium, Room 101 Young Hall

10:30–12:30 SECTIONAL MEETINGS

11:30–1:30 CAFETERIA LUNCH: Venetian Room, Cowan Dining Commons

ANTHROPOLOGY
Room 252 Young Hall
D. Van Gerven, Chairman, Presiding
Michael B. Collins, Secretary

Saturday, 2 November 1974

10:30 Reciprocity and the concept of being beholden. C. Richards, Department of Sociology and Anthropology, Transylvania University

10:50 Quantitative cross-cultural comparison of narrative content. R. Levy, Department of Anthropology, University of Kentucky

11:10 Wild plant utilization, identification and classification among selected low-income central Kentucky families. J. D. Wyss, Department of Anthropology, University of Kentucky

11:30 Takelma generative verb morphology. M. Britton, Western Kentucky State University

BOTANY AND MICROBIOLOGY
Room 101 Doherty Hall
Harold E. Eversmeyer, Chairman, Presiding
Joe E. Winstead, Secretary

Saturday, 2 November

10:30 The comparison of two methods for nitrate determinations in Barren River and its tributaries. P. Elliott and F. R. Toman, Department of Biology, Western Kentucky State University

10:45 A dry season (summer) count of total and fecal coliform bacteria in Wilmore Branch of Jessamine Creek above and below the site for the sewage disposal plant of Wilmore, Kentucky. E. Walker (sponsored by H. H. Howell), Department of Biology, Asbury College

11:00 Sterol metabolism in the fungi *Pythium* and *Phytophthora.* J. W. Hendrix, Department of Plant Pathology, University of Kentucky

11:15 Autecology of local populations of *Liquidambar styraciflua* L. W. R. Randel and J. E. Winstead, Department of Biology, Western Kentucky State University

11:30 Diameter distribution of dominant tree taxa in a mature eastern Kentucky forest. W. H. Martin, General Studies Science Program, Eastern Kentucky State University

11:45 The flora of Jessamine Gorge. J. MacGregor and W. Meijer, Department of Botany, University of Kentucky

12:00 Seasonal variations in the flora of Raven Run, Fayette County, Kentucky. C. Andre and W. Meijer, Department of Botany, University of Kentucky

12:15 Flora and vegetation of the Lexington–Metro Area in relation to urban development. W. Meijer, Department of Botany, University of Kentucky

12:30 Analysis of a climax forest system and tor-

nado damage in northern Kentucky. M. E. Held and J. E. Winstead, Department of Biology, Western Kentucky State University

12:45 Carnes Mill, a southern Indiana outlier of the mixed mesophytic forest. R. R. Van Stockum, Jr. (sponsored by A. T. Hotchkiss), Department of Biology, University of Louisville

CHEMISTRY

Room 203 Grant Hall
Joseph Hendon, Chairman, Presiding
James C. Letton, Secretary

Friday, 1 November

1:20 The general harmonic force field of fluoroform. M. Wilt, Department of Chemistry, Centre College

1:40 Oxygen determination in Kentucky #9 coal. L. L. Chyi, C. Hamrin, Jr., P. S. Maa, and W. D. Ehmann, Department of Chemistry, University of Kentucky

2:00 Transition of metal complexes of diethylamino acetonitrile. F. Wells and H. M. Smiley, Department of Chemistry, Eastern Kentucky State University

2:20 Partial kinetic resolution of α-phenylbutyric acid using chiral primary amines and their salts. A. W. Gordon and A. F. Bridges, Department of Chemistry, Murray State University

2:40 Cyclic neutron activation analysis techniques as applied to the elemental analysis of lunar samples. M. S. Maa and W. D. Ehmann, Department of Chemistry, University of Kentucky

3:00 Electron inpact mass spectra of bromoquinolines and isoquinolines, methylquinolines, and haloalkylquinolines. M. Gordon, J. Butler, and P. C. Goodley. Department of Chemistry, Murray State University

3:20 Radiation chemistry of peroxydiphosphate anions. G. Levy, Department of Chemistry, Berea College

Saturday, 2 November

10:40 Excess volumes of n-hexadecane and the isomers of hexane. J. Reeder, Department of Chemistry, Eastern Kentucky State University

11:00 Activity coefficients in the absorbed phase: carbon disulfide-acetone on two carbons. Preliminary results. M. T. Coltharp and S. Furnish, Department of Chemistry, Kentucky State University

11:20 Enhancement of atomic absorption sensitivity for copper, cadmium, antimony, arsenic, and selenium by means of solvent extraction. B. E. McClellan and J. C. Chambers, Department of Chemistry, Murray State University

1:40 Oxidation of tin(II) by hydrogen peroxide. J. Niewahner, Department of Chemistry, Northern Kentucky State College

2:00 Cobalt(I) complexes with aromatic isocyanides and trialkylphosphites. C. Becker (sponsored by J. C. Letton), Department of Chemistry, Kentucky State University

2:20 Studies on the mechanism of the reaction of osmium tetroxide with alkenes. R. L. Clark, Department of Chemistry, Somerset Community College

2:40 The phenyl proton chemical shift of para-substituted benzenediazonium compounds complexed with inorganic salts. C. Girard, Department of Chemistry, Centre College

3:00 Catalytic hydrogenation in a series of 3-substituted quinolines. E. V. Brown, L. Hough, D. W. Schluter, and H. H. Bauer, Department of Chemistry, University of Kentucky

3:20 The long-range effects and interrelationships of specific fatty acids and vitamin E on the absorption of water. I. Ahmad, J. C. Letton, and D. Cornelius, Department of Chemistry, Kentucky State University

GEOGRAPHY

Room 405 Grant Hall
Charles M. Dupier, Jr., Chairman, Presiding
Dennis L. Spetz, Secretary

Friday, 1 November

1:30 Louisville's black community: a preliminary spatial investigation. J. L. Anderson, Geography Department, University of Louisville

1:50 A socioeconomic appraisal of the substate administrative system in Kentucky. J. V. Panayotoff, Geography Department, Eastern Kentucky State University

2:10 People and politics: the distribution of population in Kentucky and its effects on Kentucky politics. J. A. Singleton, Eastern Kentucky State University

2:30 Effective employment as a relative measure of economic development. C. M. Dupier, Jr., Geography Department, Cumberland College

3:20 Means of evaluating impact of the Ohio River on economic development within the Louisville SMSA. D. E. Bierman, Geography Department, University of Louisville

3:40 Kentucky's major highway routes and corridors, 1955–1974. W. A. Withington, Geography Department, University of Kentucky

4:00 Exurban commuting and energy consumption in Kentucky. P. D. Phillips, Geography Department, University of Kentucky

4:20 Secular changes in local mean temperatures: the case of Kentucky. C. M. Dupier, Jr., Geography Department, Cumberland College

Saturday, 2 November

10:30 Geography Section Business Meeting and Election of Officers
11:00 Discussion of Special Projects in Geography

GEOLOGY

Room 409 Grant Hall
Harry P. Hoge, Chairman, Presiding
Armin L. Clark, Secretary

Friday, 1 November

1:00 An earthquake history of Kentucky. G. R. Keller, Department of Geology, University of Kentucky, and B. R. Fish, Department for Natural Resources and Environmental Protection, Frankfort, Kentucky
1:15 Geologic aspects of coal mine roof control. D. K. Hylbert (sponsored by J. C. Philley), Department of Geology, Morehead State University
1:30 A gravity and magnetic study of the southern bluegrass region, Kentucky. J. K. Greenberg, A. E. Bland, G. R. Keller, H. E. Adams, and L. L. Covert (all sponsored by G. R. Keller), Department of Geology, University of Kentucky
1:45 Volcano–Tectonic evolution of the northeastern part of the Mogollon–Datil volcanic field, New Mexico. E. Deal (sponsored by H. P. Hoge), Department of Geology, Eastern Kentucky State University
2:05 Petrographic analysis of the Boyle dolomite (Devonian) of eastern Kentucky. H. P. Hoge, Department of Geology, Eastern Kentucky State University, and S. W. Berkheiser, Atlantic Richfield, Denver, Colorado
2:25 Preliminary conodont biostratigraphy of the Boyle dolomite (Devonian) of eastern Kentucky. C. T. Helfrich, Department of Geology, Eastern Kentucky State University
2:45 Holocene history of Cape Canaveral, Florida. N. C. Hester, Department of Geology, Eastern Kentucky State University
3:05 Bedding plane conodont assemblages from the New Albany Shale of east-central Kentucky. P. B. Wigley, Department of Geology, Eastern Kentucky State University
3:25 Conodonts from the St. Louis member of the Newman formation of east-central Kentucky. P. B. Wigley, Department of Geology, Eastern Kentucky State University, and R. A. MacGill, Florida Geological Survey, Tallahassee, Florida
3:45 Correlation of Kentucky coal seams. L. Chiyi (sponsored by A. L. Clark) and G. E. Smith, Institute for Mining and Minerals Research, University of Kentucky

PHYSICS

Room 201 Doherty Hall
Frank Butler, Chairman, Presiding
William E. Maddox, Secretary

Friday, 1 November

2:50 Rapid variations in the optical brightness of compact extragalactic radio sources of the lacterid class. K. R. Hackney and R. L. Hackney, Department of Physics, Western Kentucky State University, A. G. Smith, R. L. Scott, R. J. Leacock, B. Q. McGimsey, and P. L. Edwards, Rosemary Hill Observatory, University of Florida
3:00 Anti-procrastination incentives in PSI. M. S. Longmire, K. R. Hackney, and N. F. Six, Department of Physics, Western Kentucky State University
3:10 An analysis of energy consumption at Thomas More College. L. S. Schuster and G. K. Miner, Department of Physics, Thomas More College
3:20 Computer simulation of expressway traffic. D. W. Schuetz and J. E. Lang, Department of Physics, Thomas More College
3:30 A secondary standard neutron detector. K. K. Sekharan, H. Laumer, and F. Gabbard, Department of Physics, University of Kentucky
3:40 Millimeter wavelength galactic astronomy at the University of Kentucky. R. A. Stokes, Department of Physics, University of Kentucky

Saturday, 2 November

11:00 Antiknock additives: Cyclopentadienyl compounds. M. A. Theissen and D. J. Boyle, Department of Physics, Thomas More College
11:10 Instrumentation for characterization of highway traffic noise. G. E. Paptzum, T. W. Backers, P. S. Nienaber, and D. J. Boyle, Department of Physics, Thomas More College
11:20 An AC apparatus for measurement of superfluid critical velocities. B. B. Sabo, Department of Physics, Thomas More College
11:30 Fraunhofer's optical glassworks. J. A. Gwinn, Department of Physics, University of Louisville
11:40 Experiences with purchasing a scanning electron microscope. F. Butler and M. McPherson, Department of Physics, Northern Kentucky State College
11:50 It's all done with mirrors. O. Wilson and S. Powell, Department of Physics, Berea College
12:00 Building a low cost planetarium. O. Wilson, Department of Physics, Berea College

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY SECTION

Room 401 Grant Hall
Sanford Jones, Chairman, Presiding
James L. Voogt, Secretary

Friday, 1 November

2:00 Interpretation of abnormal activities of alkaline phosphatase in sera of elderly patients. M. S. Jones, Cynthiana Hospital, Cynthiana, Kentucky

2:15 Calcitonin in the adrenalectomized rat. M. Lineberry and L. Wiate, Department of Pharmacology, University of Louisville

2:30 Plasma prolactin levels in ovariectomized rats following subcutaneous and intracarotid injection of estradiol. D. Wood and J. Vogt, Department of Physiology, University of Louisville

2:45 Quantitating brain microtubules by electron microscopy—a progress report. F. R. Toman, Western Kentucky State University, and P. Filner, Michigan State University

3:00 Analog estimation of whole nerve bundle activity. J. R. Riehm and J. R. Meyer, Department of Physiology, University of Louisville

Saturday, 2 November

11:00 Hormone receptors in breast carcinoma. R. Hahnel, King Edward Memorial Hospital for Women, Perth, Western Australia. A special 60-minute "state of the art" talk by this visiting professor at the University of Louisville

PSYCHOLOGY

Room 106 Young Hall
Richard D. Kahoe, Chairman, Presiding
Francis H. Osborne, Secretary

Saturday, 2 November

10:30 The effects of hippocampal lesions on the acquisition of a learned taste aversion with CS preexposure. D. J. McFarland, K. M. Hines, J. Kostas, and W. G. Drew, Department of Psychiatry, University of Kentucky Medical School

10:45 The effects of THC on the acquisition of a learned taste aversion with CS preexposure. D. J. McFarland, J. Kostas, K. M. Hines, and W. G. Drew, Department of Psychiatry, University of Kentucky Medical School

11:00 A preliminary evaluation of a contingency contractin approach to the introductory statistics course. F. H. Osborne, W. K. Redmon, and J. W. Moore, Department of Psychology, Morehead State University

11:15 Training college students as nonprofessional helpers. R. W. Genthner and H. Page (sponsored by W. Watkins), Department of Psychology, Eastern Kentucky State University

11:30 The psychological effects of expressway noise pollution on learning. M. J. Schmidt, R. J. Linz, C. L. Gabel, J. M. Cahill, and C. E. Rolfsen (sponsored by G. W. Menzer), Department of Psychology, Thomas More College

11:45 Psychological bases of the two-child norm. R. D. Kahoe, Department of Psychology, Georgetown College

12:00 Business Meeting and Election of Officers

SCIENCE EDUCATION

Room 205 Doherty Hall
Betty J. Stoess, Chairwoman, Presiding
Robert J. Miller, Secretary

Saturday, 2 November

10:45 Survey of Kentucky Teachers of Science-Analysis. G. K. Miner, Thomas More College

11:00 Preliminary findings survey of instructional materials utilized in Kentucky county elementary schools. B. J. Stoess, Eastern Kentucky State University

11:30 Preliminary findings: Survey of inservice science education in Kentucky county elementary schools. R. J. Miller, Eastern Kentucky State University

SOCIOLOGY

Room 206 Young Hall
Alban Wheeler, Chairman, Presiding
Henry Chang, Secretary

Friday, 1 November

1:00 What is a family. J. S. Wittman, Jr., Western Kentucky State University

1:25 Overcoming survey syndrome in eastern Kentucky. V. Arnett, University of Kentucky

1:50 The children of southern Appalachia. H. Chang, Morehead State University

3:00 Panel Discussion: Developmental change in Kentucky: The 1940's and 1970's compared. Organizer: H. W. Beers, University of Kentucky

Saturday, 2 November

10:30 Student evaluation of faculty: The other side—corruption of faculty and social work responsibility. C. P. Wilson and D. A. Miller, University of Kentucky

10:55 Post-hospital experiences of former mental patients and stigma in the occupational setting. J. G. Odom, University of Kentucky

11:20 Group definition through use of the observational unit act. T. T. McKinney, Eastern Kentucky State University

ZOOLOGY

Room 102 Young Hall
Ben T. Feese, Chairman, Presiding
Robert A. Kuehne, Secretary

Friday, 1 November

1:15 Kentucky leafhoppers. P. H. Freytag, Department of Entomology, University of Kentucky

1:30 Leafhoppers and their allies as nematode hosts. C. A. Sperka, Department of Entomology, University of Kentucky

1:45 Studies on the immune state produced in mice by the dwarf tapeworm, *Hymenolepis nana*. S. Patton, Department of Biological Sciences, University of Kentucky

2:00 A study of some of the ecological factors affecting the occurrence of water willow (*Justicia americana*) in Jessamine Creek. H. H. Howell, L. Martin, and B. Christensen, Department of Biology, Asbury College

2:15 Insect survey in Kentucky. D. Barnett, Department of Entomology, University of Kentucky

2:30 Response of arctic amphipods to environmental stress. M. Busdosh and R. M. Atlas, Department of Biology, University of Louisville

2:45 Preliminary studies on nestling barn swallow energetics. B. A. Lensing, Department of Biology, University of Louisville

3:00 Speed of recovery in a small creek after sewage pollution abatement. R. Kuehne, Department of Biological Sciences, University of Kentucky

Saturday, 2 November

10:30 Surface morphology of elasmobranch cestodes by scanning electron microscopy. F. H. Whittaker, Department of Biology, University of Louisville

10:45 Cucurbit resistance to the two-spotted spider mite. P. A. Knipping, C. G. Patterson, J. G. Rodriguez, and D. E. Knavel, Department of Entomology, University of Kentucky

11:00 Real and potential problems from the presence of *Corbicula manilensis* in Kentucky. E. Hartowicz, Department of Biology, Western Kentucky State University

11:15 Chemical factors in tomato resistance to the two-spotted spider mite. C. G. Patterson, R. R. Kemp, J. G. Rodriguez, and D. E. Knavel, Department of Entomology, University of Kentucky

11:30 Butterfly captures by Malaise traps in Kentucky. C. V. Covell, Jr., Department of Biology, University of Louisville

11:45 Preliminary observations on Kentucky Psocoptera (Insecta). L. K. Haag, Department of Biology, University of Louisville

12:00 *Ichthyophthirius multifilis* Fouquet 1876 (Ciliatea, Hymenostomatida): Natural and artificial infections. T. R. Kozel, Department of Biology, University of Louisville

KENTUCKY ACADEMY OF SCIENCE

Sectional Officers 1974–1975

Anthropology
Richard Levy (Chm)
Department of Anthropology
University of Kentucky
Lexington, KY 40506
M. B. Collins (Sec)
Department of Anthropology
University of Kentucky
Lexington, KY 40506

Botany and Microbiology
Harold E. Eversmeyer (Chm)
Department of Biology
Murray State University
Murray, KY 42072
Joe E. Winstead (Sec)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101

Chemistry
Dr. James Letton (Chm)
Department of Chemistry
Kentucky State University
Frankfort, KY 40601
Dr. Joseph Hendon (Sec)
Department of Chemistry
Murray State University
Murray, KY 42072

Geography
Dennis L. Spetz (Chm)
Department of Geography
University of Louisville
Louisville, KY 40208
Wilford A. Bladen
Department of Geography
University of Kentucky
Lexington, KY 40506

Geology
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University of Kentucky
Lexington, KY 40503
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Department of Geology
Eastern Kentucky University
Richmond, KY 40475

Physiology, Biophysics, Pharmacology
James L. Voogt (Chm)
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University of Louisville Medical School
Louisville, KY 40201
Sanford L. Jones (Sec)
Department of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475

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University of Kentucky
Lexington, KY 40506
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Department of Education
University of Kentucky
Lexington, KY 40506

Sociology
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Department of Sociology & Anthropology
Western Kentucky University
Bowling Green, KY 42101
Craig Taylor (Sec)
Department of Sociology & Anthropology
Western Kentucky University
Bowling Green, KY 42101

Psychology
Francis H. Osborne (Chm)
Department of Psychology
Morehead State University
Morehead, KY 40351
Brent C. White (Sec)
Department of Psychology
Centre College
Danville, KY 40422

Zoology
J. G. Rodriguez (Chm)
Department of Entomology
University of Kentucky
Lexington, KY 40506
Henry H. Howell (Sec)
Biology Department
Asbury College
Wilmore, KY 40390

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Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and, once accepted, an attempt will be made to publish papers in the order of their acceptance. Manuscripts should be typed, double spaced throughout, on good quality white paper 8½ × 11 inches (216 × 279 mm). The original and one copy should be sent to the Editor and the author should retain a copy for his own use in correcting proof. Metric and Celsius units are to be used for all measurements instead of, or in addition to, English and Fahrenheit units. Format and style may vary somewhat depending on the scientific discipline, but the basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of papers in the Journals of the American Chemical Society, the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and A Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined.

The sequence of material in the manuscript should be: title page, abstract, body of the manuscript, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the author's name and address, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the body of the paper.

3. The body of the manuscript should include the following sections: Introduction, Acknowledgments (if applicable), Materials and Methods, Results, Discussion, Summary, and Literature Cited. In manuscripts of only a few pages, there is no need to break it up into sections, except for the Literature Cited. All tables and figures, as well as all literature cited must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to, as in the following examples:

Article:

Johnson, A. E., and E. V. Harrell. 1962. An analysis of factors governing density patterns in desert plants. J. Bot. 44(3):419–432.

Book:

Darlington, P. J., Jr. 1965. Biogeography of the southern end of the world. Harvard Univ. Press, Cambridge, Mass. 236 pp.

5. Each table, together with its heading, must be double spaced, numbered in arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

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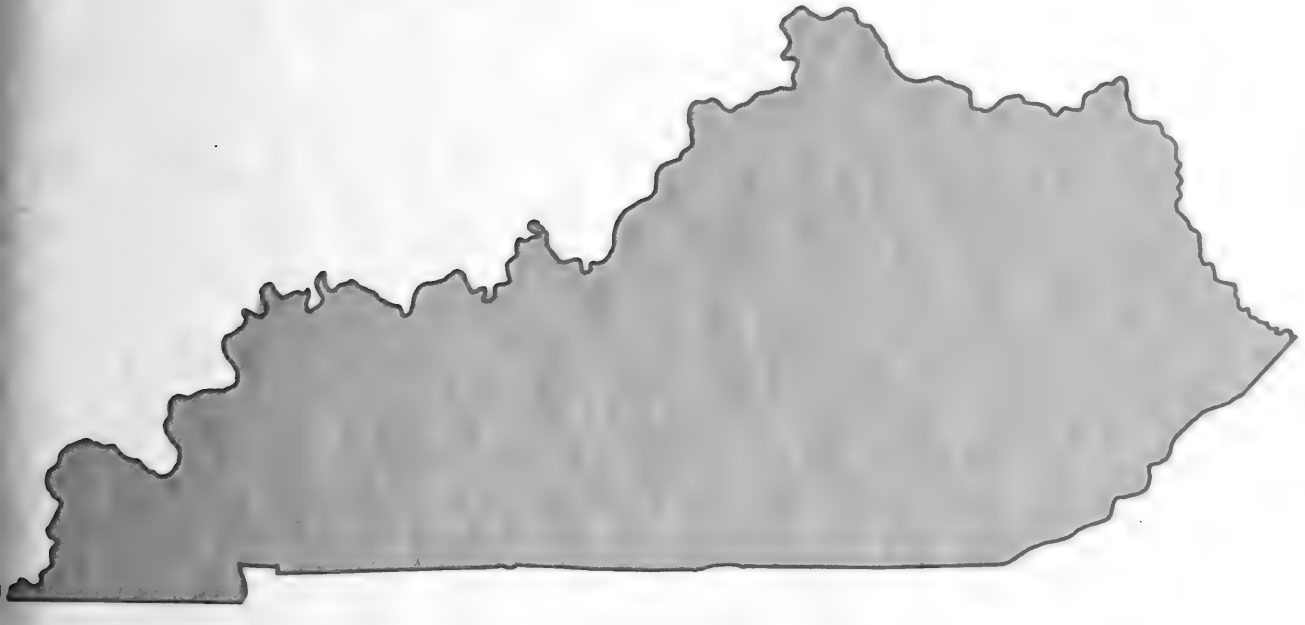

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Effective Employment as a Relative Measure of Regional Economic Development

C. M. Dupier, Jr.
Department of Geography, Cumberland College,
Williamsburg, Kentucky 40769

Abstract

Recent efforts to involve local citizenry in Area Development District activities in Kentucky has tended to preclude funding expenditures for scientific analyses to aid in regional economic development. The paper presents an intermediate analytical methodology which will reveal regional economic needs. The method falls short of an input–output analysis, but is more reliable and useful than a hastily produced regional inventory. The method uses the regression of employment and income on a where earned basis. The residuals from regression are mapped to show areas which have the most and least effective mixes of employment in the broad industrial sector of the economy. From this, the Area Development Districts' councils can determine the real needs of their regions and focus development efforts in more productive channels.

Introduction

Purpose of the Study

The construction of models to evaluate regional economic structures for the purpose of future developmental design has been a popular frustration for the past 4 decades. They began formally with the Tennessee Valley Authority in 1933 and have continued through other regional development programs such as those affecting some major river basins, Standard Metropolitan Statistical Areas, and entire states. Recently, such concepts as Area Development Districts (Kentucky Program Development Office 1970) have revolutionized and decentralized planning authority to the extent that local citizen groups have a stronger voice, if not a direct hand, in developmental design and implementation.

The very fact that the decentralization of authority has occurred, however, has altered budgetary priorities to the extent that large expenditures for the analyses of economic structures has taken a back seat to large expenditures for involving the local citizenry in decision making. This is not to say that analysis should be more important than the involvement of the people, but local input–output analyses (Miernyk 1965), economic base studies (Tiebout 1962), or intersectoral flows analyses (Hansen and Tiebout 1963) are necessary for a complete understanding of the structural interrelationships which determine the economic health of a region. Not only are they necessary, they are expensive.

This paper is designed to explore an intermediate analytical method for regionalizing developmental needs in Kentucky—a method which falls somewhere between a windshield survey and an input–output analysis.

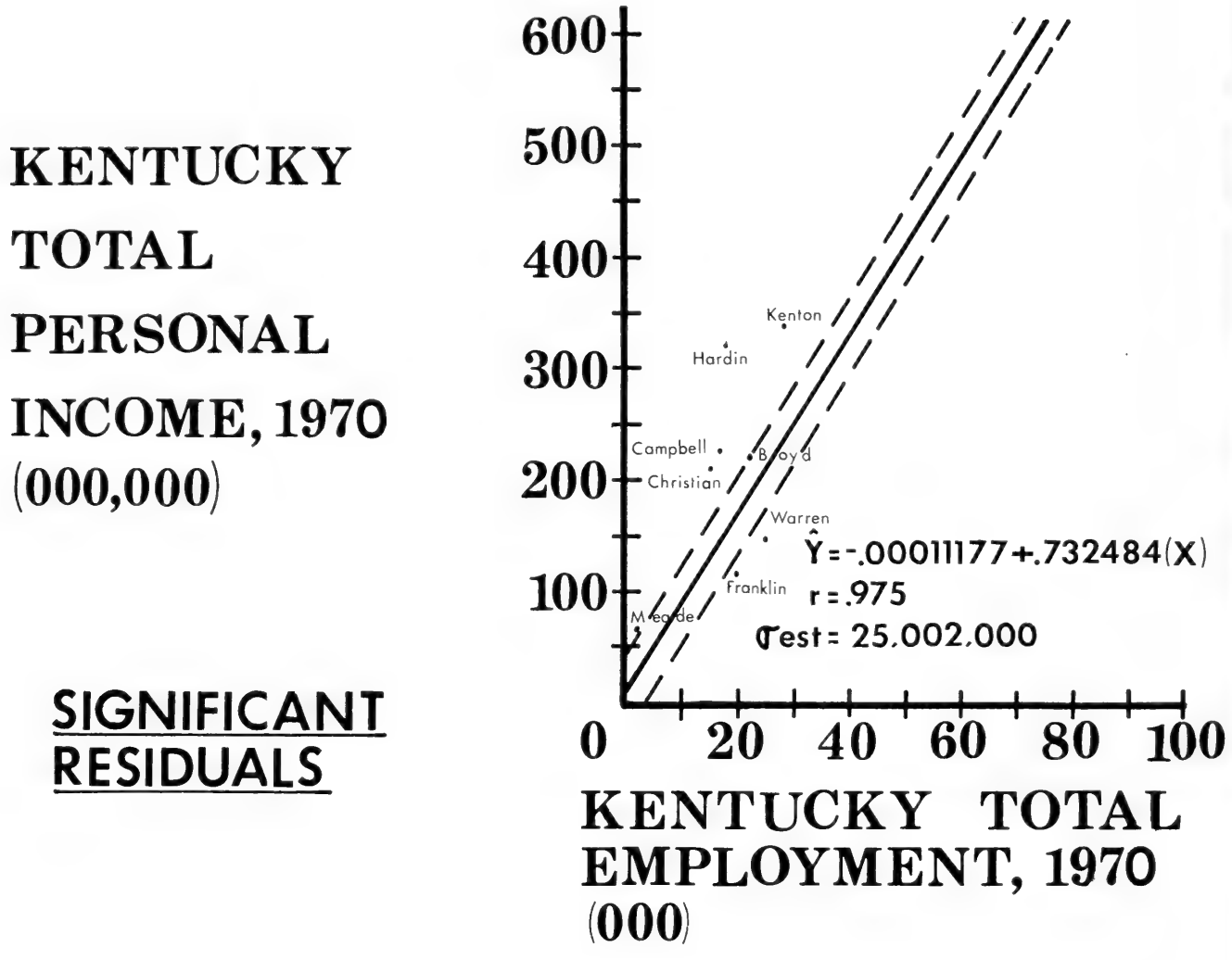

FIG. 1. Comparison of total personal income and total employment in Kentucky, 1970.

Scope of the Study

Of the broad industrial factors most important to the economic health of a region, effective employment must rank at or near the top along with the viability of the intersectoral flows of income (economic interactions). Since employment is consistently utilized as a proxy for production (Nourse 1968:148) the value of production generates greater regional income by way of the multiplier effect as it flows through the mix of regional industries, a comparative measure derived from the relationship between total employment and total personal income will reflect the effectiveness of the employment between regions, and will produce a relative indication of the makeup and/or mix of the existing sources of employment, especially in the manufacturing sector of the regional economy. Total personal income is measured on a where earned or place of work basis (this excludes income derived from extraregional sources) (Charlesworth and Curley 1970). Total employment is measured on a place of work basis by the Kentucky Department of Economic Security, therefore excluding extraregional employment sources.

This study will use 1970 data and will concentrate on the Commonwealth of Kentucky as a base region for planning. The data will be presented on the county level which will permit a usable scale for intrastate regionalization.

METHOD OF ANALYSIS

Analysis will be accomplished by the use of a linear regression model so that the covariance between total personal income and total employment can be established and

the residuals from regression analyzed for the purpose of establishing regions of employment effectiveness.

The regionalization of employment effectiveness should help to determine the most and least effective structural diversity of or total reliance upon certain employment sources. This determination can be of significant value to Area Development Districts and local citizen groups who are engaged in the recruitment of employment sources for their areas. This method of determining employment effectiveness will not identify the quantity of impact on a particular employment source (such as an industrial type) on the various sectors of the economy, but it will identify broad employment sources as potentially having either positive or negative impact on the effective employment of a region.

ANALYZING THE DATA

Application of the Statistical Model

Total personal income data are available from the Office of Business Economics, U.S. Department of Commerce, Washington, D.C. (1970). Total employment data are available from the Kentucky Department of Economic Security, Frankfort, Kentucky (Kentucky Directory of Manufacturers 1969).

The principal problems encountered in working with these data were the skewness of the distributions. Both distributions were finally brought into normality by reducing each variable to the log (log [log(x)]). The data for Jefferson County (Louisville), in both cases, had to be dropped because it could not be pulled into the normalized distributions.

A Monroe 1766 W-1 programmable calculator was used to process the data. The results of the regression model were (Fig. 1):

$$r = .975$$

$$est = \$25{,}000{,}000$$

$$\hat{Y} = -.00011177 + .732484\ (X)$$

Where X = total employment

$\hat{Y}$ = total personal income

Analysis of the Results

Those counties which were identified as being either 1 standard estimate of error above or below the trend line were examined as to their manufacturing employment source makeup. Those above 1 standard estimate of error have a predicted total personal income greater than normal (very effective employment); those below 1 standard estimate of error had predicted total personal income less than normal (very ineffective employment).

The following counties had very effective employment sources (Kentucky Directory of Manufacturers 1969):

Boyd County,—70 percent of all industrial employment is in SIC 33 (primary metals).

Campbell County,—43 percent of all industrial employment is in SIC 34–38 (fabricated metals, machinery, electrical machinery, transportation equipment, and instruments).

Christian County,—49 percent of all industrial employment is in SIC 33–38; 15 percent of the total labor force is in Federal Civil Service positions at Fort Campbell.

Hardin County,—60 percent of all industrial employment is in SIC 28 (chemicals and allied products), and SIC 34–38; 21 per cent of the total labor force is in Federal Civil Service positions at Fort Knox.

Kenton County,—60 percent of the total industrial labor force is in SIC 28 and 33–38.

Meade County,—93 percent of the total industrial labor force is in SIC 28.

The following counties had very ineffective employment sources (9):

Franklin County,—62 percent of the total industrial labor force is in SIC 20 (food and kindred products) and SIC 23 (apparel and related products); 23 percent of the total labor force are in State Civil Service positions and custodial services contracted to state agencies.

Warren County,—42 percent of the industrial labor force is in SIC 20 and SIC 24–25

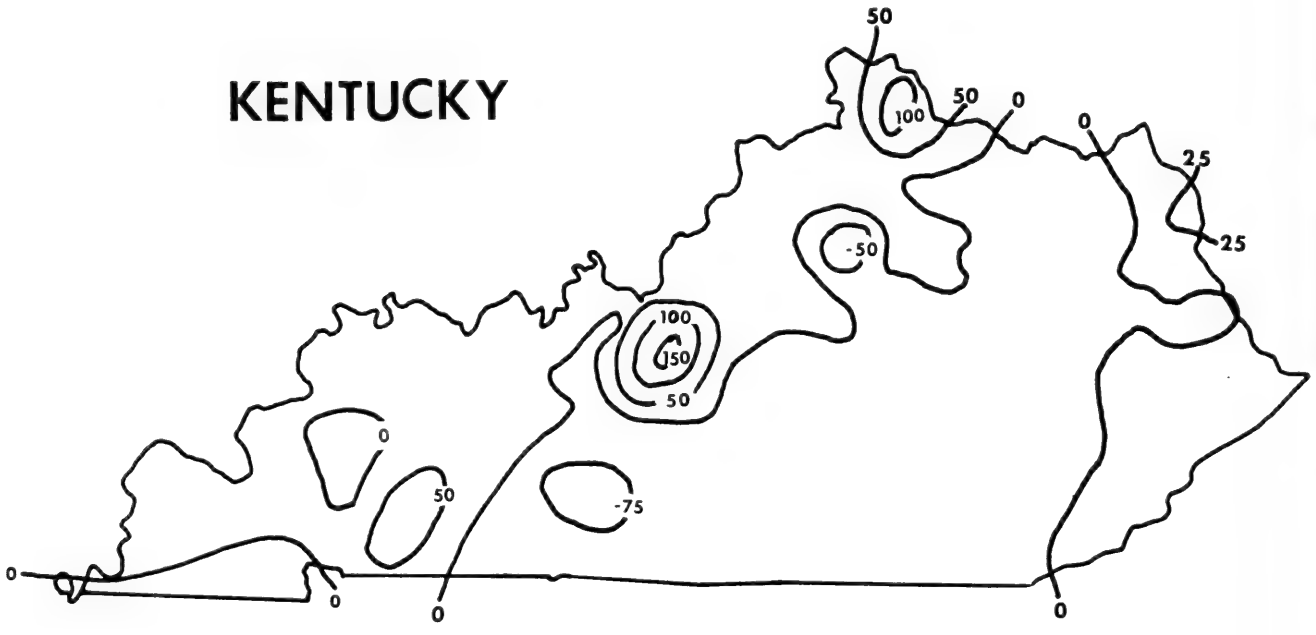

FIG. 2. Employment effectiveness surface for Kentucky, 1970.

(lumber and wood products, and furniture and fixtures) and SIC 23. Nearly 30 percent of all industrial jobs are filled by females.

The Employment Effectiveness Surface

The above counties provide peaks or depressions in the total employment effectiveness surface of Kentucky. When all the residuals from regression are plotted and the complete surface illustrated (Fig. 2), 4 primary regions are evident.

The most effective employment in the state is in the region along the Ohio River corridor from Cincinnati–Covington–Newport to Paducah, and encompasses all but 2 counties in western Kentucky. Two other regions of very effective employment are (1) from Portsmouth, Ohio, to Lawrence County, south of the Huntington–Ashland SMSA and (2) the 6 counties comprising the heart of the Eastern Kentucky Coal Fields. These regions contain 71 percent of all industrial employment, 90 percent of all employment in SIC 28–30, 92 percent of all employment in SIC 3, and 74 percent of all employment in SIC 34–38.

The region of least effective employment includes the Pennyroyal area, the Central Bluegrass, and most of the Eastern Mountain and Coal Fields. The points of least effectiveness in this region are Bowling Green, Somerset, Frankfort, Lexington, and Richmond. This region has only 29 percent of all industrial employment in the state, 26 percent of all employment in the region is in SIC 34–38, 8 percent of all employment in the region is in SIC 33, and 10 percent of all regional employment is in SIC 28–30. It has 59 percent of all employment in the state in SIC 22, 23, and 31 (apparel, textiles, and leather products).

CONCLUSIONS

The method of investigation which has been described adequately specifies, according to these preliminary investigations, the regions where employment most and least effectively generates personal income in Kentucky. The methodology can easily be replicated in other states.

Use of this methodology does not, of course, give us a complete analysis of the economic base or the intersectoral flows of income; but it does adequately set forth an index of planning priorities between and within regions which can be readily accomplished and grasped by lay interests as well as the more sophisticated personnel involved in regional economic development.

According to the case in point, the region of least effective employment—southern,

central, and eastern Kentucky—has only one-third of all industrial employment in the state and 59 percent of all the least effective industrial employment sources in the state, and should, therefore, become a focal region in state planning for the selective recruiting of more effective employment sources.

The economic needs of less effective regions cannot be cured overnight or even within a decade, under normal circumstances; but information concerning selective industrial recruitment can be more clearly disseminated to the ADD districts and local citizen groups. This is one way to effectively orient local and regional development interests to an economic growth plan which will ensure greater effectiveness in employment growth.

The need is imminent because these areas are currently opening up by way of new transportation routes which will be especially inviting to the more mobile and less effective employment sources which usually descend upon new areas of advantage with many promises of quick success and few apologies for leaving in the middle of the night.

LITERATURE CITED

CHARLESWORTH, H. K., AND M. O. CURLEY. 1971. Kentucky personal income study. Office of Development Services and Business Research, College of Business and Economics, University of Kentucky, Lexington, Ky. 4 pp.

HANSEN, W. L., AND C. M. TIEBOUT. 1963. An intersectoral flows analysis of the California economy. Rev. Econ. Stat. 45:409–418.

KENTUCKY DIRECTORY OF MANUFACTURERS. 1969. Department of Commerce, Frankfort, Ky. Pp. 139–244.

KENTUCKY PROGRAM DEVELOPMENT OFFICE. 1970. A guide for multi-county planning and development. Frankfort, Ky.

MIERNYK, W. 1965. The elements of input–output analysis. Random House, Inc. New York, N.Y.

NOURSE, H. O. 1968. Regional economics. McGraw-Hill Book Co. New York, N.Y.

TIEBOUT, C. M. 1962. The community economic base study. Suppl. Pap. No. 16. (Committee for Economic Development, Dec. 1962).

UNITED STATES DEPARTMENT OF COMMERCE. 1970. Personal income by major sources and earnings by broad industrial sector. Regional Economics Information System, Office of Business Economics. Washington, D.C. Books I through V.

A Distributional Study of the Caddisflies of Kentucky[1]

VINCENT H. RESH[2]
Water Resources Laboratory, University of Louisville,
Louisville, Kentucky 40208

ABSTRACT

Distributional records and range of adult capture are presented for 175 species of caddisflies (Trichoptera), representing 15 families and 53 genera, collected in Kentucky. Most species belong to the families Hydropsychidae, Hydroptilidae, and Leptoceridae. Based on particle size preference in feeding, most species of Kentucky caddisflies should be classified either as predators or collectors, rather than as typical shredders of the family Limnephilidae. The paucity of nontemporary pool limnephilids, mainly in the subfamily Limnephilinae, may be related to the quality of allochthonous material in Kentucky streams. Immature and adult stages have been associated for 40 percent of the species of caddisflies from Kentucky. Life history features of several leptocerid and hydroptilid caddisflies are frequently characterized by multiple cohorts and a variety of behavioral mechanisms. The use of faunal collections in environmental assessments is recommended.

INTRODUCTION

Caddisflies have long been of interest to naturalists because of the unusual case building activity of the larvae and the striking color pattern of certain species in the adult stage. To the aquatic biologist, caddisflies are extremely important as indicators of water quality, and also as a major component in the diet of fishes. The distribution and morphology of several species of Trichoptera has also been used by systematists in analyzing zoogeographical patterns of dispersal and mechanisms of speciation.

There have been few studies of caddisflies that included specimens or records from Kentucky, and Ross (1944) listed only 46 species from the state. This was obviously a small percentage of the total caddisfly fauna when compared to the number of species then known from nearby midwestern states. Since then, descriptions of new species by Ross (1959), Ross and Yamamoto (1965), and Resh (1974) have included specimens from Kentucky in the type series. Etnier (1973) reported range extensions of three species into Kentucky, and ecological studies by Minckley (1963) on Doe Run, Minshall (1968) on Morgans Creek, and Resh and Haag (1973) on the Salt River, have supplied additional distributional information.

ACKNOWLEDGMENTS

I am indebted to several people for assistance through this study. Dr. Herbert H. Ross, University of Georgia, provided numerous distributional records, specimens, and encouragement in completing this study. The original impetus for developing a faunal list for Kentucky came from the statewide collections made by Dr. Charles Covell, Jr., University of Louisville. Drs. Paul Freytag, University of Kentucky, and David Etnier, University of Tennessee, also provided specimens that increased the comprehensiveness of this work. Several taxonomists assisted in confirming the identification of difficult species. I thank Dr. John Unzicker, Illinois Natural History Survey, for his general assistance, particularly with females of *Hydropsyche* and Drs. John Morse and Elizabeth Ann Gordon, University of Georgia, for their respective assistance with *Nyctiophylax* and *Cheumatopsyche*. Drs. Stuart Neff and David White, University of Louisville, aided in the collection and sorting of specimens. I thank Dr. Freytag, Dr. Morse, and Dr. Louis A.

[1] Contribution No. 172, (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

[2] Present Address: Department of Biology, Ball State University, Muncie, Indiana 47306.

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THE CADDISFLY FAUNA

In this study, records are provided for 175 species that represent 15 families and 53 genera collected in Kentucky. This almost quadruples the number of species previously reported from the state (Ross 1944). The localities of these collections are indicated in Fig. 1.

The largest number of species (57) was collected in Spencer County. Although it is one of the smallest counties in the state, two of its streams, Brashears Creek and the Salt River, have been the subject of detailed biological investigations since 1967 (Neff and Krumholz 1973). In descending order, the following counties had the majority of caddisfly species: Breathitt Co., 41 species; Anderson Co., 32 species; Bell Co., 30 species; Johnson Co., 29 species; Fayette Co., 26 species; Rockcastle Co., 24 species; Jefferson Co., 20 species; Oldham, Trigg, and McCreary Cos., 19 species each. All other counties from which collections are known had fewer than 19 species.

The caddisfly fauna of Kentucky is extremely diverse. In areas where detailed studies have been made, large numbers of species have been collected. However, several areas in Kentucky have been entirely overlooked by collectors. From Fig. 1, it can be seen that the Licking River and Tygarts Creek drainages in Northern Kentucky, and the Green River drainage in Western Kentucky are gaps that must be filled before the distribution of Kentucky caddisflies can be described accurately.

In numbers of species, the present fauna of Kentucky is comparable to that reported from adjacent midwestern states (Ross 1944, Leonard and Leonard 1949, Etnier 1965, Unzicker et al. 1970, Longridge and Hilsenhoff 1973). With the exception of the Sericostomatidae, all North American caddisfly families are represented. However, the small number of caddisfly records in the Limnephilidae is quite unusual. In most faunal studies, this is the dominant caddisfly family, contributing both the maximum number of species and a higher percentage of individuals than most of the other families. For example, in light trap collections from the Salt River basin in central Kentucky that extended from early spring through late fall, more than 87,000 adult specimens were collected, but only a single specimen, a *Limnephilus* female, belonged to the Limnephilidae.

The limnephilids reported in this study are typical of the species in this family that utilize the temporary pool and stream habitat, particularly the genera *Ironoquia* and *Neophylax* (Clifford 1966, Wiggins 1973). It should also be noted that the largest subfamily, the Limnephilinae, is composed largely of *shredders*, that is, detritivores that decompose particles of vascular plant tissue larger than 1 mm (Cummins 1973). Using this same classification scheme, the majority of Kentucky caddisflies should not be classified as *shredders* but rather as *predators*, such as the Rhyacophilidae and Hydropsychidae, or *collectors*, those species that filter or scrape algal cells and decomposing organic matter less than 1 mm in particle size. The Limnephilinae have undergone great speciation in the Western United States (Nimmo 1971, Schmid 1955). It is very likely that the quality of the leaf fall or allochthonous input, in the woodland streams has also affected their success in the western states and influenced the relatively sparse fauna in the midwestern and southern states.

Faunal lists are a valuable source of baseline data that can be used in the preparation of an environmental assessment of an area and in monitoring temporal changes in environmental quality (Resh and Unzicker 1975). An example of the latter application of these lists and collections can be seen by examining the temporal change in the distribution of *Neophylax ayanus*, originally described from collections from Bear-

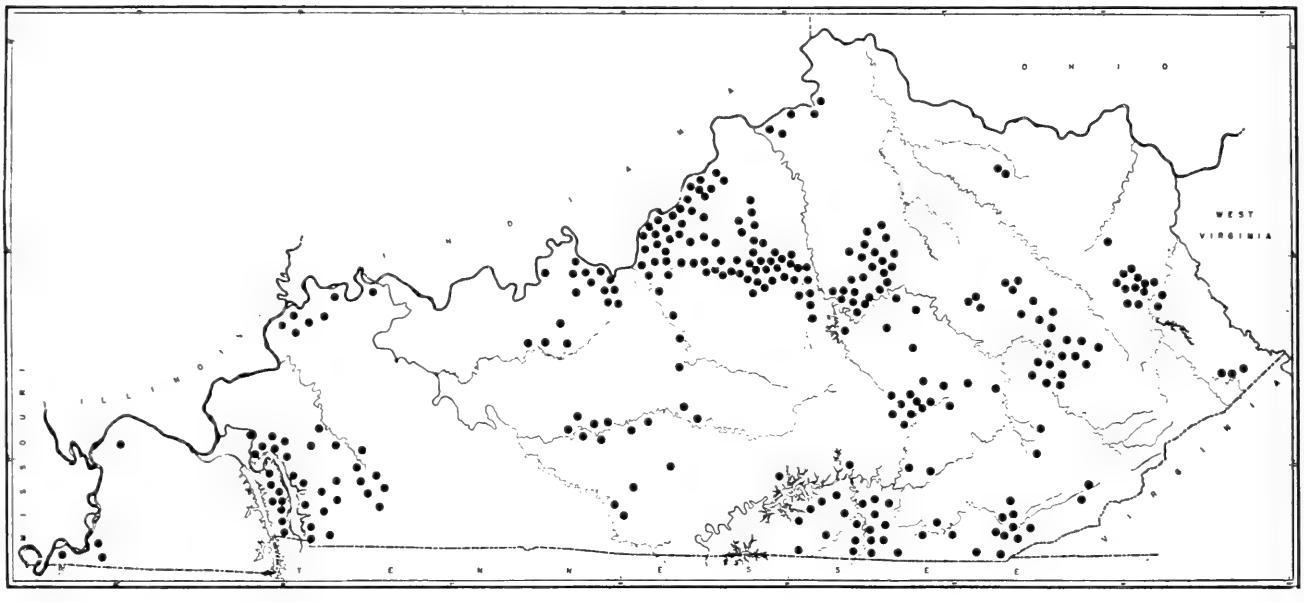

FIG. 1. Map of Kentucky indicating localities of caddisfly collections used in this study.

grass Creek in 1937 (Ross 1938). This urban stream that traverses Louisville has undergone many changes due to increases in domestic sewage and industrial discharges. The absence of *N. ayanus* from collections taken at the same localities 35 years later (1972) indicates the low tolerance of this species to the environmental changes that have occurred.

Immature Stages and Specific Level Identification

A critical problem in studies of aquatic insects is the lack of association of the immature aquatic stages with the taxonomically known aerial adult stage (Wiggins 1966). Since keys for identifying larval or pupal stages to species have yet to be developed for most genera, specific level identifications must be based on either specimens that have been reared to adults, or on adult collections. Preserved benthic samples are of little use in providing distributional information because of our inability to identify these larval specimens to the species level. This is especially true in Kentucky where such common genera as *Cheumatopsyche* and *Hydropsyche* are very poorly known in the larval stages.

Adult caddisflies, however, are quite easily collected, using a variety of ultraviolet light traps. Since most adults are evening fliers, daytime sweeping can be done in typical resting places as on the undersides of bridges, and on tree trunks. While this type of collecting can be productive, a good deal of experience and expertise is required if a representative collection of the caddisflies in the area is to be made. However, certain daytime fliers will not be attracted to light, and a program of daytime sweeping is the only way of collecting them.

During the course of the present study, immature and adult stages were associated for over 40 percent of the species reported here. In addition, detailed life history information was gathered on species of *Ceraclea* (= *Athripsodes*) and *Cheumatopsyche*, the polycentropodid *Nyctiophylax affinis*, and several hydroptilids. Caddisflies rarely have the simple life histories that have been generalized from the few North American species that have been previously examined. Instead, populations are often characterized by multiple cohorts, and in a single caddisfly genus a variety of casemaking, feeding, and behavioral mechanisms may be present. Of particular interest among the Kentucky caddisflies are the unusual features of the life cycle of *Ceraclea transversa* and *C. resurgens*, as both species feed directly on freshwater sponge (Porifera: Spongillidae). In an equally bizarre fashion, larvae and pupae of the hydroptilid caddisfly, *Dibusa angata*, attach their leath-

ery cases directly to the thallus of the freshwater red alga, *Lemanea*. These and other life histories of Kentucky caddisflies will be reported in more detail elsewhere.

THE CADDISFLIES OF KENTUCKY

The records used in this distributional study are from the collections of the Water Resources Laboratory (WRL) and the Harvey B. Lovell Memorial Insect Collection of the University of Louisville (UL), and the Entomology collections of the University of Kentucky (UK), University of Tennessee (UT), and the Illinois Natural History Survey (INHS). The WRL collections were made during preimpoundment surveys, particularly in central and eastern Kentucky.

The following list is based on collections from light traps and larval and pupal rearings (Resh 1972). As with any attempted faunal delineation, this list is by no means complete and is intended to serve as a basis for other studies. The dates refer to the range of adult capture, while those annotated with "imm" refer to collections of immature specimens and those species reared in the laboratory.

For several species, "nr" has been inserted prior to the specific name, indicating that the specimens examined were near or closest to that described species. This usually represented an identification based on a small series of specimens that did not agree totally with diagnostic or descriptive characters of the closest related species. These specimens may represent undescribed species, or variations in previously described species. These specimens have been examined by Trichoptera specialists and are presented in the hope that future collecting and analysis of a larger series of specimens from these localities, will help determine their correct taxonomic status. The nomenclatural changes in the Leptoceridae follow those of Flint (1974) and Morse (1975).

RHYACOPHILIDAE

Rhyacophila appalachia Morse and Ross
Breathitt Co., Robinson Forest, 14 June (UK).

Rhyacophila carolina Banks
Anderson Co., Salt R., 7–14 May (WRL); Breathitt Co., Robinson Forest (Falling Rock Cr.), 18 May–14 June (UK); Fayette Co., Lexington (Tates Cr.), 8 June (UK); Jessamine Co., Indian Falls, 29 April (UK); McCreary Co., Cumberland Falls State Park (Eagle Cr.), 16 March (UK); Menifee Co., Murder Cave, 23 October (INHS); Powell Co., Natural Bridge State Park, 13 July (UL); Rockcastle Co., Horselick Cr., 17 May (WRL); Shelby and Spencer Cos., Brashears Cr., 11–14 May (WRL); Spencer Co., Salt R., 11 May (WRL).

Rhyacophila carpenteri Milne
Hart Co., Mammoth Cave National Park (Good Springs), 20 May (INHS); Madison Co., Dog Foot Springs, 6 June (UK); Meade Co., Otter Cr. Park (Morgans Cr.), imm (INHS).

Rhyacophila fenestra Ross
Fayette Co., Steeles Run, 24 April (UK); Shelby Co., Shelbyville (Brashears Cr.), 20 April (WRL).

Rhyacophila glaberrima Ulmer
Hart Co., Mammoth Cave National Park, 8 April–20 May (INHS); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL).

Rhyacophila ledra Ross
Fayette Co., Evans Mill (Raven Run), 27 May (INHS); Wayne Co., Little Fork of Cumberland R., 18 May (UT).

Rhyacophila lobifera Betten
Fayette Co., Raven Run, 6 May (INHS) and Boone Cr., 10 May (UK); Jefferson Co., May (UL); Jessamine Co., Indian Falls, imm (UK); Shelby and Spencer Cos., Brashears Cr., 7 May (WRL); Spencer Co., Salt R., 30 April (WRL).

Rhyacophila minor Banks
McCreary Co., Cumberland Falls, 12 May (INHS); Menifee Co., Red R., 17 April (UK).

Rhyacophila otica Etnier and Wray
Breathitt Co., Robinson Forest, 14 June (UK).

Rhyacophila parantra Ross
Fayette Co., Lexington, 9 June (UK); Garrard Co., Buena Vista (Ison Cave), 31 May (INHS); Hart Co., Mammoth Cave (Spring Run), 20 May (INHS); Madison Co., Dog Foot Springs, 6 June (UK); Meade Co., Morgans Cr., 7 June (INHS).

Rhyacophila torva Hagen
Jessamine Co., Indian Falls, 29 April (UK).

GLOSSOSOMATIDAE

Agapetus hessi Leonard and Leonard
Wayne Co., Little So. Fork of Cumberland R., 18 May (Etnier 1973).

Agapetus illini Ross
Christian Co., Hopkinsville, 26 April (INHS); Fayette Co., 24 April (UK); Jessamine Co., Indian Falls, imm (UK); Mercer Co., Harrodsburg, 10 July (INHS).

Agapetus nr *rossi* Denning
Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

Agapetus tomus Ross
Breathitt Co., Robinson Forest, 14 June (UK); Green Co., 4 May (INHS).

Glossosoma intermedium
Meade Co., Morgans Cr., 15 March (INHS).

Glossosoma nigrior (Banks)
Hart Co., Hardyville (Zoo Springs), 16 June (INHS); Meade Co., Doe Run, 7 November (INHS).

Matrioptila jeanae (Ross)
Bell Co., Pineville (Cumberland R.), 13 June (INHS); McCreary Co., Cumberland Falls, 12 May–12 June (INHS); Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

Protoptila alexanderi Ross
Union Co., Sturgis, 22 August (INHS).

Protoptila maculata (Hagen)
Anderson Co., Salt R., 30 April–21 September (WRL); Bell Co., Pineville (Cumberland R.), 24 June (INHS); Shelby and Spencer Cos., Brashears Cr., 7 May–20 September (WRL); Spencer Co., Salt R., 31 May–1 October (WRL).

Protoptila palina Ross
Bell Co., Pineville (Cumberland R.), 28 August (INHS).

Philopotamidae

Chimarra aterrima Hagen
Anderson Co., 3 July (UK); Fayette Co., Lexington, 19 May (UK), Raven Cr., May (INHS), Steeles Run, imm (UK) and Boone Creek, imm (UK); Harlan Co., 12 June (INHS); Jefferson Co., Louisville (Beargrass Cr.), 2 June (INHS); Jessamine Co., Indian Falls (Hickman Cr.), 24 April (UK) and Marble Cr., imm (UK); McCreary Co., Cumberland Falls State Park, imm (Eagle Cr.), (UK); Oldham Co., Covered Bridge Boy Scout Camp, 19 April (UL).

Chimarra feria Ross
Fayette Co., Lexington (Tates Cr.), 8 June (UK).

Chimarra obscura (Walker)
Anderson Co., Salt R., 7 May–27 September (WRL); Breathitt Co., Quicksand, 8 May (INHS); Fayette Co., Lexington, 13 April–30 July (UK); Jefferson Co., Beargrass Cr., 16 June (INHS); Jessamine Co., Kentucky R., imm (UK); Johnson Co., Paintsville (Paint Cr.), 21 June–31 August (WRL); Powell Co., Natural Bridge State Park, 11 August (INHS); Shelby and Spencer Cos., Brashears Cr., 1 May–19 September (WRL); Spencer Co., Salt R., 11 May–19 September (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK).

Chimarra nr *obscura* (Walker)
Fayette Co., Lexington, 30 June (UK).

Chimarra socia Hagen
Bell Co., Pineville (Cumberland R.), 13 June (INHS).

Dolophiloides distinctus (Walker)
Breathitt Co., Robinson Forest, 14 June (UK); Powell Co., Natural Bridge State Park, 8 February–1 March (UK); Wolfe Co., Mill Cr., 2 March (UK).

Wormaldia moesta (Banks)
Jackson Co., Hicksey Cave, 5 June (INHS); Meade Co., Otter Creek Park (Morgans Cr.), 1 February (INHS); Menifee Co., Murder Cave, 23 October (INHS); Powell Co., Natural Bridge State Park, 1 March (UK); Wolfe Co., Mill Creek, 2 March (UK).

Wormaldia nr *moesta* (Banks)
Whitely Co., Anvil Bridge (Cumberland R.), imm (UK).

Wormaldia shawnee Ross
Christian Co., Hopkinsville, imm (INHS).

Psychomyiidae

Cernotina nr *calcea* Ross
Anderson Co., Salt R., 25 June (WRL); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 9 July (WRL).

Lype diversa (Banks)
Breathitt Co., Robinson Forest, 14 June (UK); McCreary Co., Cumberland Falls, 12 May (INHS); Meade Co., Doe Run, 30 April–1 June (INHS); Rockcastle Co., Horselick Cr., 17 May (WRL); Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

Psychomyia flavida (Hagen)
Bell Co., Pineville (Cumberland R.), 24 June–28 August (INHS); Breathitt Co., Robinson Forest, 14 June (UK); Henderson Co., Henderson, 27 June (INHS); Laurel Co., Livingston (Rockcastle R.), 16 June (INHS); McCreary Co., Cumberland Falls, 12 May (INHS); Meade Co., Doe Run, 17 June–21 July (INHS, WRL, UL); Rockcastle Co., Horselick Cr., 17 May (WRL).

Polycentropodidae

Cyrnellus fraternus (Banks)
Anderson Co., Salt R., 10 June–20 September (WRL); Fayette Co., Lexington, 10 June–25 August (UL); Fulton Co., Bondurant, 27 August (INHS); Hart Co., Hardyville (Green R.), 15 June (INHS); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Meade Co., Otter Cr. Park (Morgans Cr.), 14 September (INHS); Shelby and Spencer Cos., Brashears Cr., 2 June–21 September (WRL); Spencer Co., Salt R., 10 June–20 September (WRL); Trigg Co., Land Between the Lakes (L. Barkley), 12–13 September (INHS); Union Co., Caseyville, 28 August (INHS).

Neureclipsis crepuscularis (Walker)
Breckinridge Co., Camp Breckinridge, 10 May (INHS); McCreary Co., Cumberland Falls, 12 May (INHS).

Neureclipsis parvulus Banks
Bell Co., Pineville, 24 June (INHS); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS).

Nyctiophylax affinis (Banks)
Anderson Co., Salt R., 25 June (WRL); Breathitt Co., Robinson Forest, 14 June (UK); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 11 May–9 September (WRL).

Nyctiophylax celta Denning
Reported by Morse (1972) from southeastern Kentucky.

Nyctiophylax uncus Ross
Reported by Morse (1972) from southeastern Kentucky.

Phylocentropus carolinus Carpenter
McCreary Co., Cumberland Falls, 12 May (INHS).

Phylocentropus hansoni (Root)
Rockcastle Co., Horselick Cr., 17 May (WRL).

Phylocentropus placidus (Banks)
Rockcastle Co., Horselick Cr., 17 May (WRL).

Polycentropus barri Ross and Yamomoto
Breathitt Co., Robinson Forest, 14 June (UK); Jackson Co., John Rogers Cave and Blowing Springs Cave, 20 May–14 July (UK) (INHS).

Polycentropus blicklei Ross and Yamomoto
Trigg Co., Land Between the Lakes, 23–24 June (UK).

Polycentropus cinereus (Hagen)
Anderson Co., Salt R., 31 May–30 September (WRL); Breathitt Co., Robinson Forest, 14 June (UK); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Oldham Co., Harrods Cr., 20 May–30 August (WRL); Shelby and Spencer Cos., Brashears Creek, 6 May–7 October (WRL); Spencer Co., Salt R., 7 May–8 October (WRL).

Polycentropus confusus Hagen
Rockcastle Co., Horselick Cr., 17 May (WRL).

Polycentropus crassicornis Walker
Breckinridge Co., Camp Breckinridge, imm (INHS).

Polycentropus elarus Ross
Barren Co., Beckton (Bryant Edmonds Cave), 14 April (INHS); Elliot Co., Gimlet (Tar Kiln Cave), 23 May (INHS); Fayette Co., Lexington (Tates Cr.), 8 June (UK); Wayne Co., Blowing Cave, 21 August (INHS).

Polycentropus maculatus Banks
Breathitt Co., Robinson Forest, 14 June (UK).

Polycentropus remotus Banks
Spencer Co., Taylorsville (Salt R.), imm (WRL).

Polycentropus sp. a
Christian Co., Hopkinsville, 28 April (INHS), cited in Ross (1944).

HYDROPSYCHIDAE

Aphropsyche doringa Milne
Johnson Co., Paintsville (Paint Cr.), 13 May (WRL).

Cheumatopsyche analis (Banks)
Anderson Co., Salt R., 30 April–20 September (WRL); Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 18 May–14 June (UK); Christian Co., June (UK); Fayette Co., Steeles Run and Lexington, 25 April–8 August (UK); Gallatin Co., Warsaw, 14 June–3 August (INHS); Green Co., Greensburg (Camp Branch Cave), 19 April (INHS); Jefferson Co., Louisville, 10 April–15 June (WRL); Jessamine Co., Indian Falls (Hickman Cr.), 24 April (UK); Johnson Co., Big Sandy R. (Open Fork) and Little Paint Cr., 9 May–3 August (WRL); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Mercer Co., Harrodsburg, 10 June (INHS); Metcalfe Co., Sulfur Cr. Cave, 16 April (INHS); Oldham Co., Horner Bird and Wildlife Sanctuary and Covered Bridge Boy Scout Camp, 14 April–18 August (WRL, UL); Rockcastle Co., Horselick Cr., 17 May (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK).

Cheumatopsyche aphanta Ross
Breathitt Co., Robinson Forest, 14 June (UK).

Cheumatopsyche burksi Ross
Oldham Co., 5 August (UL).

Cheumatopsyche campyla Ross
Christian Co., 8 June (UK); Breathitt Co., Robinson Forest, 14 June (UK); Bullitt Co., Smithville (Salt R.), 23 May (UL) and 27 September (INHS); Fayette Co., Lexington, 3 July (UK); Oldham Co., 25 May (UL); Rockcastle Co., Horselick Cr., 17 May (WRL); Shelby and Spencer Cos., Brashears Cr., 30 April–1 October (WRL); Spencer Co., Salt R., 24 April–7 October (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK).

Cheumatopsyche goera Denning
Trigg Co., Land Between the Lakes, 23–24 June (UK).

Cheumatopsyche harwoodi harwoodi Denning
Bell Co., Pineville, (Gordon 1972 unpublished doctoral dissertation, University of Georgia, Athens, Ga.).

Cheumatopsyche helma Ross
Bell Co., Pineville, 24 June (INHS).

Cheumatopsyche minuscula (Banks)
Pulaski Co., Burnside, 11 June (INHS).

Cheumatopsyche nr *rossi* (Gordon n.n. unpublished doctoral dissertation)
Fayette Co., Lexington, 20 April–1 May (UK).

Cheumatopsyche oxa Ross
Jefferson Co., 1 May (UL); Jessamine Co., Indian Falls, 29 April (UK); Johnson Co., Paintsville (Paint Cr.), 21 June–31 August (WRL); Leslie Co., Pine Mountain (Greasy Cr.), 25–26 April (INHS); Powell Co., Nat-

ural Bridge State Park, 11 August (INHS), and Slade, 8 May (INHS); Warren Co., 18 June (UK).

Cheumatopsyche pasella Ross
Bell Co., Pineville, 24 June–28 August (INHS); McCreary Co., Cumberland 12 May (INHS); Spencer Co., Salt R., 16 June (WRL).

Cheumatopsyche sordida (Hagen)
Bell Co., Pineville, 28 August (INHS); McCreary Co., Cumberland Falls, 12 May (INHS); Rockcastle Co., Livingston (Rockcastle R.), 15–16 June (INHS).

Diplectrona modesta Banks
Breathitt Co., Robinson Forest, imm (UK), Jackson, imm (UK), and Quicksand, 8 May–14 June (INHS); Bullitt Co., 23 May (UL); Edmonson Co., Mammoth Cave (Good Springs), 20 May (INHS); Johnson Co., Paintsville (Paint Cr.), 31 August (WRL); Meade Co., Morgans Cr., 7 September (INHS) and Doe Run, (Minckley 1963); Oldham Co., 14 July–6 August (UL); Owsley Co., Booneville, imm (INHS); Wolfe Co., 1–13 July (UL).

Hydropsyche betteni Ross
Breathitt Co., Robinson Forest, 14 June (UK); Bullitt Co., 23 May–28 July (UL); Jessamine Co., Indian Falls, 29 April (UK); Johnson Co., Paintsville (Paint Cr.), 31 August (WRL); Oldham Co., Horner Bird and Wildlife Sanctuary, 18 May–18 August (WRL, UL); Russell Co., Jamestown, 18–25 May (UL); Shelby and Spencer Cos., Brashears Cr., 6 May–7 June (WRL); Spencer Co., Salt R., 7 May–16 July (WRL); Wolfe Co., 13 July (UL).

Hydropsyche bronta Ross
Breathitt Co., Robinson Forest, 14 June (WRL).

Hydropsyche cheilonis Ross
Rockcastle Co., Horselick Cr., 17 May (WRL); Spencer Co., Salt R., 25–26 June (WRL).

Hydropsyche depravata (Hagen)
Caldwell Co., Princeton (Eddy Cr.), 20 April (INHS); Lyon Co., Eddyville (Cumberland R.), 3 August (INHS); Meade Co., Doe Run, 2 February–21 July (INHS, UL); Warren Co., 18 June (UK).

Hydropsyche dicantha Ross
Bell Co., Pineville, 24 June (INHS); Rockcastle Co., Horselick Cr., 17 May (WRL); Spencer Co., Salt R., 21 June–14 September (WRL).

Hydropsyche hageni Banks
Bell Co., Pineville, 24 June (INHS); McCreary Co., Cumberland Falls, 27 April–12 May (UK, INHS).

Hydropsyche incommoda Hagen
Fayette Co., Lexington, 20 July (UK); Rockcastle Co., Horselick Cr., 17 May (WRL); Spencer Co., Salt R., 25 June–10 July (WRL).

Hydropsyche morosa Hagen
Breathitt Co., Robinson Forest, 14 June (WRL).

Hydropsyche orris Ross
Christian Co., June (UK); Fayette Co., Lexington, 26 June–3 August (UK); Fulton Co., Bondurant, 6 September (INHS); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Oldham Co., Horner Bird and Wildlife Sanctuary, 18 May–5 August (WRL, UL); Spencer Co., Salt R., 31 May (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK).

Hydropsyche phalerata Hagen
Bell Co., Pineville, 24 June (INHS); McCreary Co., Cumberland Falls, 24 April (UK).

Hydropsyche simulans Ross
Breathitt Co., Quicksand, 6 May (INHS); Breckinridge Co., Camp Breckinridge, imm (INHS); Caldwell Co., Princeton (Eddy Cr.), 3 August (INHS); Christian Co., June (UK); Jefferson Co., 13 July (UL); Henderson Co., 27 June (INHS); McCreary Co., Cumberland Falls, 27 April (UK); Spencer Co., Salt R., 7 June–21 September (WRL).

Hydropsyche sparna Ross
Breathitt Co., Robinson Forest, 14 June (UK); Leslie Co., Lilley Cornett Woods, 11–12 July (UL); Rockcastle Co., Horselick Cr., 17 May (WRL).

Hydropsyche valanis Ross
Spencer Co., Salt R., 16 July (WRL).

Hydropsyche venularis Banks
Bell Co., Pineville, 24 June (INHS).

Macronemum zebratum Hagen
Bell Co., Pineville (Cumberland R.), 24 June (INHS), Harlan Co.; 12 June (INHS).

Potamyia flava (Hagen)
Ballard Co., 24 May (UK); Fayette Co., Lexington, 20 July (UK); Fulton Co., Bondurant, 23 August–1 September (INHS); Gallatin Co., Warsaw (Ohio R.), 1 July–3 August (INHS); Hart Co., Hardyville (Green R.), 15 June (INHS); Henderson Co., Henderson, 12 May (INHS); Jefferson Co., 9 May–13 July (UL); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Oldham Co., 14 June (UL); Spencer Co., Brashears Cr., 9–15 July (WRL); Spencer Co., Salt R., 7 July–22 August (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK); Union Co., Sturgis, 4 July–31 August (INHS) and Caseyville, 28 August (INHS).

HYDROPTILIDAE

Agraylea multipunctata Curtis
Meade Co., Doe Run (Minckley 1963).

Dibusa angata Ross
Jessamine Co., Indian Falls, 24–29 April (UK); Johnson Co., Paintsville (Paint Cr.), 8 May (WRL); McCreary Co., Cumberland Falls, 12 May (INHS).

Hydroptila ajax Ross
Spencer Co., Brashears Cr. and Salt R., May–9 September (WRL).

Hydroptila nr *ajax* Ross
Johnson Co., Paintsville (Paint Cr.), 21 June (WRL).
Hydroptila amoena Ross
Rockcastle Co., Horselick Cr., 17 May (WRL).
Hydroptila angusta Ross
Anderson Co., Salt R., 25 June (WRL); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 7 June–24 September (WRL).
Hydroptila armata Ross
Anderson Co., Salt R., 31 May–9 September (WRL): Shelby and Spencer Cos., Brashears Cr., 25 May–9 September (WRL); Spencer Co., Salt R., 21 May–20 September (WRL).
Hydroptila consimilis Morton
Anderson Co., Salt R., 24 June (WRL); Breathitt Co., Robinson Forest, 14 June (UK).
Hydroptila nr *consimilis* Morton
Breathitt Co., Robinson Forest, 14 June (UK).
Hydroptila delineata Morton
Whitley Co., Cumberland Falls, 27 April (UK).
Hydroptila grandiosa Ross
Johnson Co., Paintsville (Paint Cr.), 21 June–14 July (WRL).
Hydroptila hamata Morton
Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 14 June (UK); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); Mercer Co., Harrodsburg, 10 June (INHS); Rockcastle Co., Livingston, 16 June (INHS); Spencer Co., Salt R., 9 September (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK).
Hydroptila perdita Morton
Anderson Co., Salt R., 1 May–7 October (WRL); Johnson Co., Paintsville (Paint Cr.), 14 July (WRL); Shelby and Spencer Cos., Brashears Cr., 30 April–1 October (WRL); Spencer Co., Salt R., 27 April–7 October (WRL).
Hydroptila spatulata Morton
Breathitt Co., Robinson Forest, 14 June (UK); Wayne Co., Little So. Fork of Cumberland R., 18 May (Etnier 1973).
Hydroptila vala Ross
Breathitt Co., Robinson Forest, 14 June (UK).
Hydroptila virgata Ross
Breathitt Co., Robinson Forest, 14 June (UK).
Hydroptila waubesiana Betten
Spencer Co., Brashears Cr. and Salt R., 10 June–19 September (WRL).
Ithytrichia mazon Ross
Spencer Co., Taylorsville (Salt R.), 10–16 June (WRL).
Mayatrichia ayama Mosely
Bell Co., Pineville, 24 June (INHS).
Neotrichia collata Morton
Ross (1944) cited as from Kentucky, no locality or data given.
Neotrichia minutisimella (Chambers)
Rockcastle Co., Livingston, 16 June (INHS).
Neotrichia okopa Ross
Anderson Co., Salt R., 25 June (WRL); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 2 June–15 July (WRL).
Neotrichia riegeli Ross
Johnson Co., Paintsville (Paint Cr.), 21 June–31 August (WRL).
Ochrotrichia anisca (Ross)
Breathitt Co., Robinson Forest, 14 June (UK).
Ochrotrichia confusa (Morton)
Jessamine Co., Indian Falls, 29 April (UK).
Ochrotrichia shawnee (Ross)
Larue Co., 16 June (UK).
Ochrotrichia spinosa (Ross)
Mercer Co., Harrodsburg, 10 June (INHS); Spencer Co., Brashears Cr., 2 June (WRL).
Ochrotrichia tarsalis (Hagen)
Spencer Co., Brashears Cr. and Salt R., 10 June–1 October (WRL).
Ochrotrichia nr *unio* (Ross)
Meade Co., Morgans Cr., imm (Minshall 1968).
Ochrotrichia xena (Ross)
Spencer Co., Brashears Cr., 11 May (WRL).
Orthotrichia aegerfasciella (Chambers)
Anderson Co., Salt R., 25 June (WRL); Breathitt Co., Robinson Forest, 14 June (UK); Fulton Co., Bondurant, 27 August (INHS); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 25 May–19 September (WRL); Trigg Co., Land Between the Lakes (Lake Barkley), 12–13 September (INHS).
Orthotrichia cristata Morton
Anderson Co., Salt R., 25 June (WRL); Spencer Co., Brashears Cr., 9 July (WRL).
Oxyethira pallida (Banks)
Anderson Co., Salt R., 25 June–9 September (WRL); Johnson Co., Paintsville (Paint Cr.), 21 June–4 August (WRL).
Stactobiella delira (Ross)
McCreary Co., Cumberland Falls, 17 April–12 May (UK, INHS); Rockcastle Co., Horselick Cr., 17 May (WRL).
Stactobiella palmata (Ross)
Anderson Co., Salt R., 2 May–25 June (WRL); Breathitt Co., Robinson Forest, 14 June (UK); Johnson Co., Paintsville (Paint Cr., and Little Paint Cr.), 31 May–21 July (WRL); McCreary Co., Cumberland Falls, 12 May (INHS); Shelby and Spencer Cos., Brashears Cr., 7 May–16 June (WRL); Spencer Co., Salt R., 1 May–29 June; Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

PHRYGANEIDAE

Agrypnia vestita (Walker)
Trigg Co., Land Between the Lakes, 16 July (WRL).
Banksiola dossuaria (Say)
Pike Co., Shelby Gap, 8–9 June (UK).
Phryganea sayi Milne
Bullitt Co., 28 July–7 September (UL); Bul-

litt Co., Shepherdsville, 25 July (WRL); Meade Co., Otter Cr. Park, 25 July (WRL); Oldham Co., 6–18 August (UL); Spencer Co., Salt R., 1–29 August (WRL).

Ptilostomis ocellifera (Walker)
Oldham Co., 12 May (UL).

Ptilostomis semifasciata (Say)
Bell Co., Pineville, 28 August (INHS); Breathitt Co., Robinson Forest, 14 June (UK).

LIMNEPHILIDAE

Pseudostenophylax uniformis (Betten)
Johnson Co., Paint Cr., 8 May (WRL).

Ironquia punctatissima (Walker)
Carroll Co., Butler State Park, 11 October (WRL); Jefferson Co., 4 October (UL); Spencer Co., Rivals, imm (WRL).

Neophylax autumnus Vorhies
Meade Co., Morgans Cr., 26 October (INHS).

Neophylax ayanus Ross
Jefferson Co., Louisville (Beargrass Cr.), 8 October (INHS).

Neophylax concinnus MacLachlan
Oldham Co., 25 November (UL); Spencer Co., Rivals, imm (WRL).

Neophylax consimilis Betten
Pike Co., Fishtrap Lake, 10 July (WRL).

Neophylax nacatus Denning
Spencer Co., Rivals, imm (WRL).

Platycentropus radiatus (Say)
Pike Co., Fishtrap Lake, 19 June (WRL).

Pycnopsyche gentilis MacLachlan
Leslie Co., Pine Mountain, 23 October (UL); Whitely Co., Cumberland Falls State Park (Cumberland R.), 15 March (UK).

Pycnopsyche guttifer (Walker)
Fayette Co., Boone Cr., (UK); Jefferson Co., Louisville, 9 October (UL).

Pycnopsyche lepida (Hagen)
Oldham Co., Covered Bridge Boy Scout Camp, 20 September–21 October, (WRL, UL).

ODONTOCERIDAE

Psilotreta rufa (Hagen)
Hart Co., Mammoth Cave National Park, 20 May (INHS).

LEPTOCERIDAE

Ceraclea (*Athripsodina*) *ancylus* (Vorhies)
Anderson Co., Salt R., 10 May–1 July (WRL); Oldham Co., Harrods Cr., (WRL); Shelby and Spencer Cos., Brashears Cr., 7 May–29 June; Spencer Co., Salt R., 7 May–1 July (WRL).

Ceraclea (*C.*) *transversa* (Hagen) (= *Athripsodes angustus* (Banks) See Morse (1975).
Anderson Co., Salt R., 25 May–10 September (WRL); Jefferson Co., Louisville (Beargrass Cr.), 16 June (INHS); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 21 May–15 September (WRL).

Ceraclea (*Athripsodina*) nr *annulicornis* (Stephens)
Trigg Co., Land Between the Lakes, 23–24 June (UK).

Ceraclea (*C.*) *cancellata* (Betten)
Anderson Co., Salt R., 10 June–3 August (WRL); Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 14 June (UK); Jefferson Co., 18 August (UL); Johnson Co., Paintsville (Paint Cr.), 21 June–14 July (WRL); Rockcastle Co., Livingston, 16 June (INHS); Shelby and Spencer Cos., Brashears Cr., 13 May–6 August (WRL); Spencer Co., Salt R., 25 May–10 August (WRL).

Ceraclea (*Athripsodina*) *flava* (Banks)
Bell Co., Pineville, 24 June (INHS); Rockcastle Co., Livingston, 16 June (INHS).

Ceraclea (*C.*) nr *fulva* (Rambur)
Spencer Co., Taylorsville (Brashears Cr.), imm (WRL).

Ceraclea (*C.*) *neffi* (Resh)
Breathitt Co., Robinson Forest, 14 June (UK); Rockcastle Co., Horselick Cr., imm (WRL).

Ceraclea (*C.*) *resurgens* (Walker)
Jefferson Co., Harrods Cr., 19 May (WRL); McCreary Co., Cumberland Falls, 12 May (INHS).

Ceraclea (*Athripsodina*) *tarsipunctatus* (Vorhies)
Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 14 June (UK); Breckenridge Co., Camp Breckenridge, imm; Christian Co., June (UK); Fayette Co., Lexington, 9 June–20 July (INHS, UK); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); McCreary Co., Cumberland Falls, 12 May (INHS); Rockcastle Co., Livingston, 16 June (INHS); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 15 June–4 July (WRL); Trigg Co., Land Between the Lakes, 23–24 June (UK).

Ceraclea (*C.*) *maculata* (Banks) (= *Athripsodes transversus* (Hagen), See Morse (1975)
Anderson Co., Salt R., 21 May–9 September (WRL); Barren Co., 3 July (UK); Fulton Co., Bondurant, 6 September (INHS); Henderson Co., Henderson, 27 June (INHS); Jefferson Co., 10–13 July (UL); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Oldham Co., Horner Bird and Wildlife Sanctuary, 18 May–5 August (UL, WRL); Shelby and Spencer Cos., Brashears Cr., 31 May–10 September (WRL); Spencer Co., Salt R., 21 May–15 September (WRL); Trigg Co., Lake Barkley, 23 June–13 September (INHS, UK).

Nectopsyche nr *albida* (Walker)
Anderson and Spencer Cos., Salt R., 25 June–19 September (WRL).

Nectopsyche candida (Hagen)
Spencer Co., Taylorsville (Salt R.), 21 June–24 September (WRL).

Nectopsyche exquisita (Walker)
Bell Co., Pineville, 24 June–28 August (INHS); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); Spencer Co., 19 June (UL); Spen-

cer and Shelby Cos., Brashears Cr., 7 May–10 October (WRL); Spencer Co., Salt R., 11 May–16 August (WRL).

Nectopsyche pavida (Hagen)
Bell Co., Pineville, 24 June (INHS); Rockcastle Co., Livingston (Rockcastle R.), 16 June (INHS).

Mystacides sepulchralis (Walker)
Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

Oecetis avara (Banks)
Bell Co., Pineville, 24 June–28 August (INHS).

Oecetis cinerascens (Hagen)
Anderson Co., Salt R., 15 May–10 September (WRL); Fayette Co., Lexington, 26 June (UK); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); Oldham Co., 18 August (UL); Spencer Co., Brashears Cr. and Salt R., 11 May–19 September (WRL); Trigg Co., Lake Barkley, 12–13 September (INHS).

Oecetis ditissa Ross
Anderson Co., Salt R., 25 June (WRL); Johnson Co., Paintsville (Paint Cr.), 21 June (WRL); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 2 June–19 September (WRL); Trigg Co., Lake Barkley, 23 June–13 September (UK, INHS).

Oecetis inconspicua (Walker)
Anderson Co., Salt R., 31 May–1 October (WRL); Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 14 June (UK); Bullitt Co., 23 May (UL); Caldwell Co., Princeton (Eddy Cr.), 3 August (INHS); Carroll Co., Gen. Butler State Park and Carrollton (Kentucky R.), 30 June–11 October (UL); Christian Co., June (UK); Fayette Co., Lexington, 10 May–25 August (UK, INHS); Fulton Co., Bondurant, 23 August (INHS); Jefferson Co., 28 May–13 July (UL); Johnson Co., Paintsville (Paint Cr.), 21 June–31 August (WRL); Lyon Co., Eddyville (Cumberland R.), 6 August (INHS); Mercer Co., Harrodsburg, 10 June (INHS); Oldham Co., Horner Bird and Wildlife Sanctuary, 18 May–5 August (WRL, UL); Rockcastle Co., Horselick Cr. and Livingston (Rockcastle R.), 17 May–16 June (WRL, INHS); Shelby and Spencer Cos., Brashears Cr., 11 May–1 October (WRL); Spencer Co., Salt R., 7 May–7 September (WRL); Trigg Co., Land Between the Lakes (Lake Barkley), 23 June–13 September (UK, INHS); Union Co., Sturgis, 31 August (INHS); Wolfe Co., 15 July (UL).

Oecetis nocturna Ross
Anderson Co., Salt R., 31 May–1 October (WRL); Fayette Co., Lexington, 10 May–17 June (UK); Johnson Co., Paintsville (Paint Cr.), 21 June–31 August (WRL); Spencer Co., Brashears Cr. and Salt R., 25 May–7 October (WRL); Trigg Co., Land Between the Lakes, 16 June–13 September (WRL, INHS).

Oecetis persimilis (Banks)
Anderson Co., Salt R., 25 June (WRL); Barren Co., 8 July (UK); Bell Co., Pineville, 24 June (INHS); Johnson Co., Paintsville (Paint Cr.), 21 June–4 August (WRL); Spencer Co., Taylorsville (Salt R.), 10 June–16 August (WRL).

Setodes incertus (Walker)
Bell Co., Pineville, 24 June–28 August (INHS).

Triaenodes abus Milne
Jefferson Co., 20 May (UL).

Triaenodes connatus Ross
Bell Co., Pineville (Cumberland R.), 24 June (INHS); Spencer Co., Taylorsville (Salt R.), 1 August–14 September (WRL).

Triaenodes nr *dipsius* (Ross)
Breathitt Co., Robinson Forest, 14 June (UK).

Triaenodes flavescens Banks
Trigg Co., Land Between the Lakes, 23 June (UK).

Triaenodes ignitus (Walker)
Spencer Co., Salt R., 25–26 June (WRL).

Triaenodes injustus (Hagen)
Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 14 June (UK).

Triaenodes melacus Ross
Anderson Co., Salt R., 25 June (WRL); Spencer Co., Taylorsville (Brashears Cr., and Salt R.), 31 May–16 August (WRL).

Triaenodes tardus Milne
Fayette Co., Lexington, 15 May–26 June (UK, INHS); Johnson Co., Paintsville (Paint Cr.), 21 June–4 August (WRL); Oldham Co., Horner Bird and Wildlife Sanctuary, 18 May–18 August (WRL, UL); Spencer Co., Taylorsville (Brashears Cr. and Salt R.), 2 June–1 October (WRL); Union Co., Sturgis, 22 August (INHS).

GOERIDAE

Goera calcerata Banks
Breathitt Co., Robinson Forest, 14 June (UK); Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

Goera stylata Ross
McCreary Co., Cumberland Falls, 12 May (INHS).

LEPIDOSTOMATIDAE

Lepidostoma griseum (Banks)
Jackson Co., Blowing Springs Cave, 24 September (INHS).

Lepidostoma togatum (Hagen)
Edmonson Co., Mammoth Cave, 3–20 May (INHS); Rockcastle Co., Livingston (Rockcastle R.), 16 June (INHS).

Theliopsyche melas Edwards
Fayette Co., Lexington, 9 June (UK).

BRACHYCENTRIDAE

Brachycentrus lateralis (Say)
Jefferson Co., Louisville (Ohio R.), May (INHS).

Brachycentrus numerosus (Say)
Jefferson Co., Louisville (Ohio R.), May (INHS).

Micrasema bennetti Ross
Fayette Co., Steeles Run, 28 March (UK).

Micrasema rusticum (Hagen)
Jessamine Co., Indian Falls, imm (UK); McCreary Co., Cumberland Falls, 12 May (INHS); Rockcastle Co., Horselick Cr., 17 May (WRL); Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

Micrasema wataga Ross
McCreary Co., Cumberland Falls, 12 May (INHS).

HELICOPSYCHIDAE

Helicopsyche borealis (Hagen)
Bell Co., Pineville, 24 June (INHS); Breathitt Co., Robinson Forest, 14 June (UK); Bullitt Co., 8 July (UL); Jefferson Co., Louisville (Beargrass Cr.), 16 June–8 October (WRL); McCreary Co., Cumberland Falls, 12 June (INHS); Meade Co., 21 July (UL); Menifee Co., Wolfpen Cr., imm (UK); Nelson Co., Beech Fork of Salt R., imm (WRL); Oldham Co., Covered Bridge Boy Scout Camp (Harrods Cr), 14 May–8 October (UL); Wayne Co., Little So. Fork of Cumberland R., 18 May (UT).

LITERATURE CITED

CLIFFORD, H. F. 1966. The ecology of invertebrates in an intermittent stream. Invest. Ind. Lakes Streams. 7:57–98.

CUMMINS, K. W. 1973. Trophic relations of aquatic insects. Ann. Rev. Ent. 18:183–206.

ETNIER, D. A. 1965. An annotated list of the Trichoptera of Minnesota with description of a new species. Entomol. News 74:141–152.

———. 1973. Extensions of the known ranges of Northern Trichoptera into the Southern Appalachians. J. Ga. Entomol. Soc. 8:272–274.

FLINT, O. S., JR. 1974. The Trichoptera of Surinam. *In* The Fauna of Suriname and Other Guyanas, No. LV:1–151.

LEONARD, J. W., AND F. A. LEONARD. 1949. An annotated list of Michigan Trichoptera. Occ. Pap. Mus. Zool. Univ. Mich. 522:1–35.

LONGRIDGE, J. L., AND W. L. HILSENHOFF. 1973. Annotated list of Trichoptera in Wisconsin. Trans. Wisc. Acad. Sci. Arts Lett. 61:173–183.

MINCKLEY, W. L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildl. Monogr. 11:1–124.

MINSHALL, G. W. 1968. Community dynamics of the benthic fauna in a woodland springbrook. Hydrobiologia 32:305–339.

MORSE, J. C. 1972. The genus *Nyctiophylax* in North America. J. Kans. Entomol. Soc. 45: 172–181.

———. 1975. A revision of the caddisfly genus *Ceraclea* Stephens (Trichoptera, Leptoceridae). Contr. Amer. Entomol. Inst. 11: 1–97.

NEFF, S. E., AND L. A. KRUMHOLZ. 1973. A detailed investigation of the sociological, economic, and ecological aspects of proposed reservoir sites in the Salt River Basin of Kentucky. Research Report No. 67. Water Resources Res. Inst., Univ. Kentucky, Lexington, Ky. 64 pp.

NIMMO, A. P. 1971. The adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and Eastern British Columbia and their postglacial origin. Quaest. Entomol. 7:3–234.

RESH, V. H. 1972. A technique for rearing caddisflies (Trichoptera). Can. Entomol. 104: 1959–1961.

———. 1974. New species of *Athripsodes* caddisflies from eastern United States (Trichoptera: Leptoceridae). J. Ga. Entomol. Soc. 9:267–269.

———, AND K. H. HAAG. 1973. Species diversity, parasitism, and flight activity of caddisflies in a Kentucky stream. Proc. N. C. Branch, Entomol. Soc. Amer. 28:155–163.

———, AND J. D. UNZICKER. 1975. Water quality monitoring and aquatic organisms: the importance of species identification. J. Water Poll. Contr. Fed. 47:9–19.

ROSS, H. H. 1938. Descriptions of nearctic caddisflies. Bull. Ill. Nat. Hist. Surv. 21:101–183.

———. 1944. The caddisflies, or Trichoptera, of Illinois. Bull. Ill. Nat. Hist. Surv. 23:1–326.

———. 1959. The relationships of three new species of *Triaenodes* from Illinois and Florida (Trichoptera). Entomol. News 70:39–45.

———, AND T. YAMAMOTO. 1965. New species of the caddisfly genus *Polycentropus* from Eastern North America (Trichoptera, Psychomyidae). Proc. Biol. Soc. Wash. 78:241–246.

SCHMID, F. 1955. Contribution a l' etude des Limnophilidae (Trichoptera). Mitt. Schweiz. ent. Ges. 28:1–245.

UNZICKER, J. D., L. AGGUS, AND L. O. WARREN. 1970. A preliminary list of the Arkansas Trichoptera. J. Ga. Entomol. Soc. 5:167–174.

WIGGINS, G. B. 1966. The critical problem of systematics in stream ecology. Pp. 55–58. *In* Cummins, K. W., C. A. Tryon and R. T. Hartman (eds.) Organism–Substrate Relationships in Streams. Spec. Publ. Pymatuning Lab. Ecology, Univ. Pittsburgh, Pittsburgh, Pa. No. 14:1–145.

———. 1973. A contribution to the biology of caddisflies (Trichoptera) in temporary pools. Life Sci. Contr. R. Ont. Mus. No. 88: 1–28.

Unusual Behavior of the Eastern Chipmunk

Pierre N. Allaire
Department of Science and Mathematics, Lees Junior College,
Jackson, Kentucky 41339

On 23 October, while approaching a small farm pond created by the reclamation of a surface mine in Breathitt County, I observed an eastern chipmunk (*Tamias striatus*) swimming toward me from the opposite shore. At first glance I thought it was a snake because of its S-shaped swimming pattern, but soon realized that it was not. I remained quiet during the entire journey (approx. 20 m/min = 1.2 km/hr), and it landed quite close to me. It shook its fur and quickly scurried into the grassy hummocks and began feeding.

Such aquatic behavior apparently is not typical. Jackson (1961:146) stated that "it prefers to keep its feet dry, yet when circumstances require it can swim well." Upon observation, I could not determine any circumstances that may have "forced" it into the water. No predators were seen, but may have been present prior to my arrival. It seems unlikely though because the pond was at least 100 m from the forest edge and at least 30 m from the taller grasses not exposed to grazing. Had it been chased by a predator it likely would have sought the safety of its burrow. I suspect it wandered away from its preferred habitat, possibly as a result of the disturbance of surface mining nearby (2–3 km). Certainly throughout the evolution of animals, wandering, whatever its primary cause, has been a part of range expansion. Evidence such as this suggests that physical barriers like water may not have been a serious obstacle in population movements of eastern chipmunks.

Of particular interest was the chipmunk's manner of aquatic locomotion. Since it is not specifically adapted for this type of environment or movement, one might have assumed it to "dog paddle" its way across a body of water. This was not the case. The entire body was involved in a constant series of S-shaped movements which appeared to use the tail to some degree in a continuous lashing manner for propulsion. One might speculate this to be a more efficient method for aquatic locomotion since the entire body is involved rather than just the appendages which could tire quickly. However, research would have to be performed to obtain quantitative data regarding the energetics in aquatic locomotion in *Tamias striatus*.

I wish to thank Wayne H. Davis for suggestions during the preparation of this manuscript.

Literature Cited

Jackson, H. H. T. 1961. Mammals of Wisconsin. Univ. Wisconsin Press, Madison, Wis. 504 pp.

The Leech *Piscicolaria reducta* Parasitizing Some Percid Fishes

BRUCE H. BAUER
Department of Biology, Tennessee Technological University,
Cookeville, Tennessee 38501

AND

BRANLEY A. BRANSON
Department of Biological Sciences, Eastern Kentucky University,
Richmond, Kentucky 40475

ABSTRACT

New host records for the leech *Piscicolaria reducta* Meyer are established from the percid fishes *Percina maculata*, *P. evides*, and 5 species of *Etheostoma*: *E. zonale*, *E. caeruleum*, *E. stigmaeum*, *E. virgatum*, and *E. blennioides*. Additional records from *Percina caprodes* are presented.

INTRODUCTION

No records of piscicolid leeches on percid fishes from Kentucky have been published in the open literature except for the recent publication of White and Crisp (1973) which listed *Piscicolaria reducta* from a single specimen of *Percina caprodes*. Meyer (1940) reported finding *Piscicolaria reducta* from *Percina phoxocephala* in Illinois, in New Jersey from *Lepomis macrochirus* (Meyer 1946), and in Maine from *Notemigonus crysoleucas* (Meyer 1954). Harms (1959) reported it from *Ictalurus melas* and *I. punctatus* in Kansas, and Klemm (1972) listed it from some of Connecticut and Michigan fishes.

This study extends the known range of and increases the list of host species for

TABLE 1.—NUMBERS OF FISHES EXAMINED, NUMBERS AND LOCATION OF LEECHES ON EACH FISH AND LOCATION WHERE FISHES WERE CAPTURED. C = CAUDAL FIN; P_1 = PECTORAL FIN; P_2 = PELVIC FIN

Host	Number of Fish Examined	Location Where Fish Captured	Number and Location of Leeches on Each Fish
Percina maculata	1	Rockcastle River: Hway 80 Crossing at Laurel–Pulaski County Line; 13 Oct 1973	1 C
P. maculata	1	Kentucky River: South Fork, Booneville, Owsley County; 17 Jul 1970	1 C
P. caprodes	1	Kentucky River: South Fork, 1 mile South of Clay–Owsley County Line; 1 Aug 1970	1 C
P. evides	1	Kentucky River: Middle Fork, Hway 30 Crossing, Breathitt County; 1 Jul 1972	2 C
Etheostoma zonale	1	Same as *P. evides*	1 C
E. virgatum	4	Rockcastle River: Hway 80 Crossing at Laurel–Pulaski County Line; 13 Oct 1973	2 C 3 C 1 C 2 P_1,P_2
E. caeruleum	1	Rockcastle River: Hway 80 Crossing at Laurel–Pulaski County Line; 13 Oct 1973	2 C
E. stigmaeum	2	Same as *E. caeruleum*	4 C 2 C
E. zonale	1	Same as *E. caeruleum*	1 C
E. zonale	1	Licking River: Hway 11 Crossing, Fleming County; 10 Nov 1973	2 P_1
E. blennioides	1	" "	2 P_1

Piscicolaria reducta. As far as we have been able to determine, this leech has never been reported from *Etheostoma.*

MATERIALS AND METHODS

The fishes were collected as part of a survey of the Kentucky, Dix, and Licking rivers by Drs. Branson and Batch of Eastern Kentucky University. The fishes were all taken with common-sense nylon minnow seines of 0.32-cm-square mesh. All fishes used in this study were collected from riffle areas composed mainly of coarse gravel and rubble. The leeches were originally preserved in 10 percent formalin, later changed to 50 percent isopropanol, and deposited in the collection of Dr. C. K. Mather, Department of Biology, Northern Illinois University, DeKalb, Illinois, who identified the specimens.

RESULTS

Table 1 lists the number of fishes examined, the numbers and locations of the leeches on each fish, and the location where the fishes were captured. All leeches were attached externally, with 77.8% attached to the caudal fin, 18.5% on the pectorals, and 3.7% on the pelvic fins.

LITERATURE CITED

HARMS, C. E. 1959. Checklist of parasites from catfishes of northeastern Kansas. Trans. Kan. Acad. Sci. 62(4):262.

KLEMM, D. J. 1972. Freshwater Leeches (Annelida: Hirudinia) of North America. Environmental Protection Agency, Project 18050 ELD. Washington, D.C. 53 pp.

MEYER, M. C. 1940. A revision of the leeches (Piscicolidae) living on freshwater fishes of North America. Trans. Amer. Microsc. Soc. 59(3):354–376.

———. 1946. Further notes on the leeches (Piscicolidae) living on freshwater fishes of North America. Trans. Amer. Microsc. Soc. 65(3):237–249.

———. (1954). 1962. The larger animal parasites of the freshwater fishes of North America. Maine Dept. Inland Fish Game, Fish. Res. Manage. Div. Bull. 1–88.

WHITE, G. E., AND N. H. CRISP. 1973. The occurrence of four leeches (Hirudinea: Rhynchobdellida: Piscicolidae) on Kentucky River drainage fishes. Trans. Ky. Acad. Sci. 34(3, 4):47–48.

A Micrographic Study of the Giant Nuclei of *Neoechinorhynchus* sp. (Acanthocephala)

David H. Leslie[1]
Western Kentucky University,
Bowling Green, Kentucky 42101

Abstract

Microscopic analyses of the giant nucleus of *Neoechinorhynchus* sp. indicate that these organelles possess a complex internal structure, and appear to be composed of 2 distinct structural regions: a peripheral lobed region and a central region. The peripheral region is composed of a series of lobes separated by invaginations of the nuclear membrane while the central region appears to contain tubular structures and a fibrous network. The giant nuclei are intimately associated with the transverse lacunar canal system via lacunar reservoirs situated above and below the nuclei. The giant nuclei of *Neoechinorhynchus* lack double unit membranes and nucleoli. The Feulgen reaction indicates the absence of DNA. The presence of a complex internal structure and absence of DNA indicate that giant nuclei have differentiated into new organelles.

Introduction

For almost 200 years investigators have observed the giant nuclei in the tegument of adult acanthocephalans. The unusually large size of the giant nuclei has presented problems in the identification of these organelles as nuclei to early investigators. Some giant nuclei have been measured up to 5 mm in length and 50 μm wide in *Macracanthorhynchus hirudinaceus*. Investigators have sought explanations for the unusual size of this organelle. Van Cleave (1951) postulated that this extreme size was due to polyploidy state. Marshall et al. (1973) and Robinson (1973) supported this postulate in their studies on the giant nuclei of *Moniliformis dubius*. Robinson clearly demonstrated the presence of a nucleolus, DNA, and a double membrane enclosing the giant nucleus.

In observing whole mounts of *Neoechinorhynchus*, stained with Harris' hematoxylin, unusual structural forms within giant nuclei were noted. These observations prompted this study of giant nuclei using a combination of light and electron microscopic techniques.

Acknowledgments

The author expresses his appreciation to Martin R. Houston, Larry N. Gleason, and Brent B. Nickol for their assistance and guidance in bringing this work to publication.

Materials and Methods

Acanthocephala used for this study were obtained from turtles purchased from

[1] Present address: University of Louisville, Louisville, Kentucky 40202.

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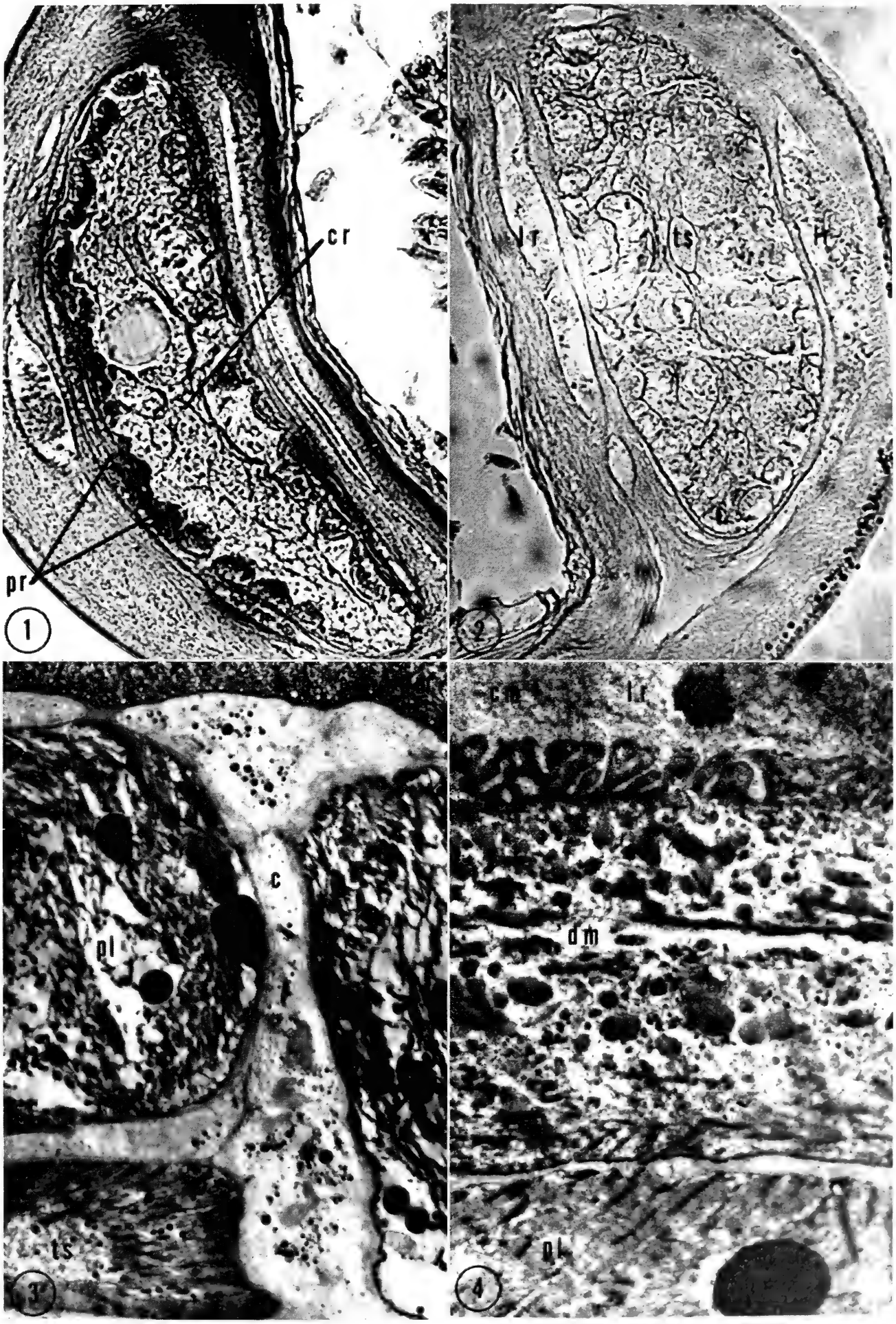
Fig. 1. Cross section through the giant nucleus stained with osmium tetroxide. The oblong nucleus appears to be divided into 2 distinct regions: a dark staining lobed peripheral region (pr), and a central region (cr) containing 1 large vesicle and an extensive fiber network. ×300.

Fig. 2. Cross section through the giant nucleus stained by the Feulgen reaction. The transverse lacunar canal below the giant nucleus bifurcated to form a lacunar reservoir (lr) on each side of the nucleus. Many tubular structures (ts) may be noted in the central region. ×400.

Fig. 3. Electron micrograph of the peripheral area and a portion of the central region. At the top is a layer of dermal material (dm) with the outer membranous structure below it. An invagination forms a canal (c) leading into the interior of the giant nucleus. These invaginating canals divide the peripheral region into peripheral lobes (pl). Below the left peripheral lobe is a tubular structure typical of those seen in the central region. ×3,000.

Fig. 4. Electron micrograph of the peripheral region of the giant nucleus and lacunar reservoir. The lacunar reservoir is separated from the dermal material by a highly convoluted membrane (cm). A lobe of the peripheral region containing large electron dense granules may be noted below the dermal material. ×5,500.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Southern Biological Supply Company. Immediately prior to experimentation, turtles were sacrificed and the worms removed from the intestine. Disposition of the worms after removal depended upon the specific study to be conducted.

Portions of the worms containing giant nuclei were embedded in paraffin and sectioned at 10 μ. The sections were stained with osmium tetroxide, or the Feulgen reaction as described by Humason (1967) for study with the light microscope. Sections of female worms bearing eggs were used for the Feulgen reaction, and selected sections of the mature female worms were designated as controls. The DNA was removed by rinsing the tissue in 0.5 N perchloric acid for 25 min. The experimental sections remained in distilled water for the same time period.

For electron microscopic study, whole worms were placed in 0.85 percent saline, and the giant nuclei carefully excised, removing as little excess dermal material as possible. The giant nuclei were fixed in 5 percent glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.2). Postfixation was completed in 1 percent osmium tetroxide in the same buffer for 20 min and then stained with 0.5 percent uranyl acetate for 2 hours. The giant nuclei were dehydrated in an ethanol and propylene oxide series followed by embedding in Epon 812. The nuclei were sectioned on a Sorvall MT-2 microtome and examined with a Ziess electron microscope, Model 9A.

Results and Discussion

When stained with osmium tetroxide, the nuclei appeared oblong in shape and varied in size depending upon location within the worm. A gradual reduction in size was noted from the large anteriorly located nuclei to the smaller posterior nuclei. Light microscopy indicated 2 distinct nuclear regions within the giant nuclei of *Neoechinorhynchus* sp.: a dark staining peripheral region and a lighter staining central region (Fig. 1). The peripheral region consisted of large lobes around the perimeter of the giant nucleus. The lobes were not always continuous around the entire periphery and sometimes were absent (Figs. 1, 2). This may indicate that not all of the giant nuclei in the same worm have similar structure due to the age, nutritional state of the worm, or the location of the giant nucleus in the worm. In many cases, fibrous networks of the central regions were observed and appeared to be continuous with the dark peripheral region (Fig. 1). At the level of light microscopy, numerous tubular structures, appearing vesicular in nature, were observed in the central region. An extensive fiber network was also observed extending throughout the region (Figs. 1, 2). The tubular structures of the central region varied in size, shape, and number. In most of the nuclei observed there was a large spherical vesicle containing a fine granular background substance (Fig. 1). This large vesicle may be analogous to the nucleolar vacuole Robinson (1973) reported in the giant nucleus of *Moniliformis dubius.*

Usually, there were 3 or 4 transverse lacunar canals in close proximity to a giant nucleus. Serial sectioning demonstrated that most of these transverse lacunar canals near a giant nucleus bifurcate to form lacunar reservoirs above and below the giant nucleus (Fig. 2). These extensions of the lacunar canals encompassing the giant nuclei would indicate a close association between the giant nuclei and the lacunar system.

The controls for the Feulgen reaction

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FIG. 5. The convoluted membrane that separates the lacunar reservoir and dermal material associated with the giant nucleus. ×12,000.

FIG. 6. A tubular structure within the central region. The medulla of this tubular structure appears to contain some small granules and the cortex appears fibrous. ×3,900.

FIG. 7. This second type of tubular structure within the central region appears to contain electron dense granules and a disrupted tubular system interlacing the granules. ×5,200.

FIG. 8. Ultrastructure of the packed fiber network within the central region. ×7,000.

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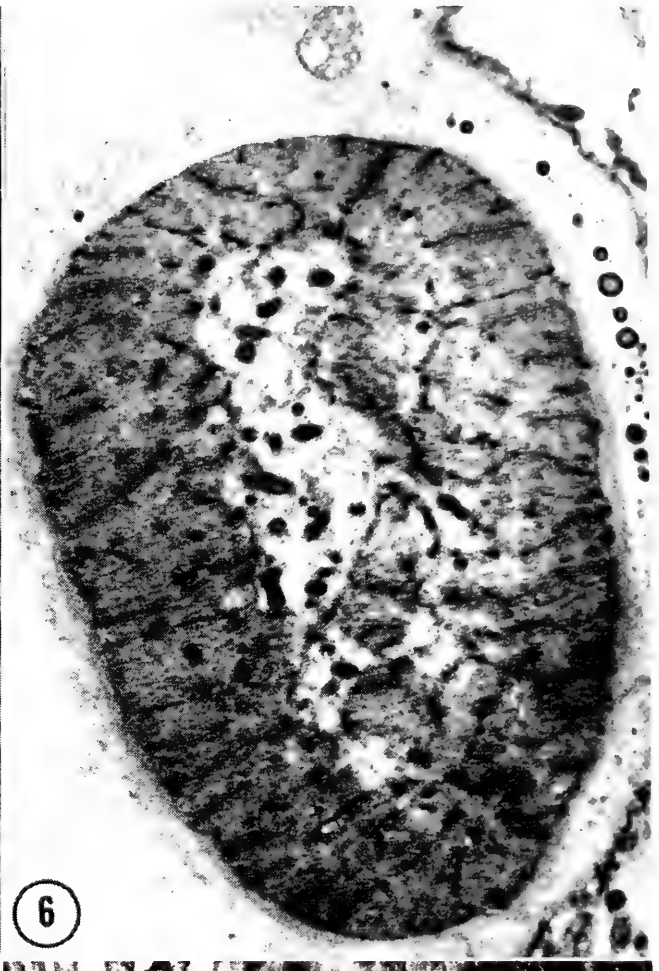

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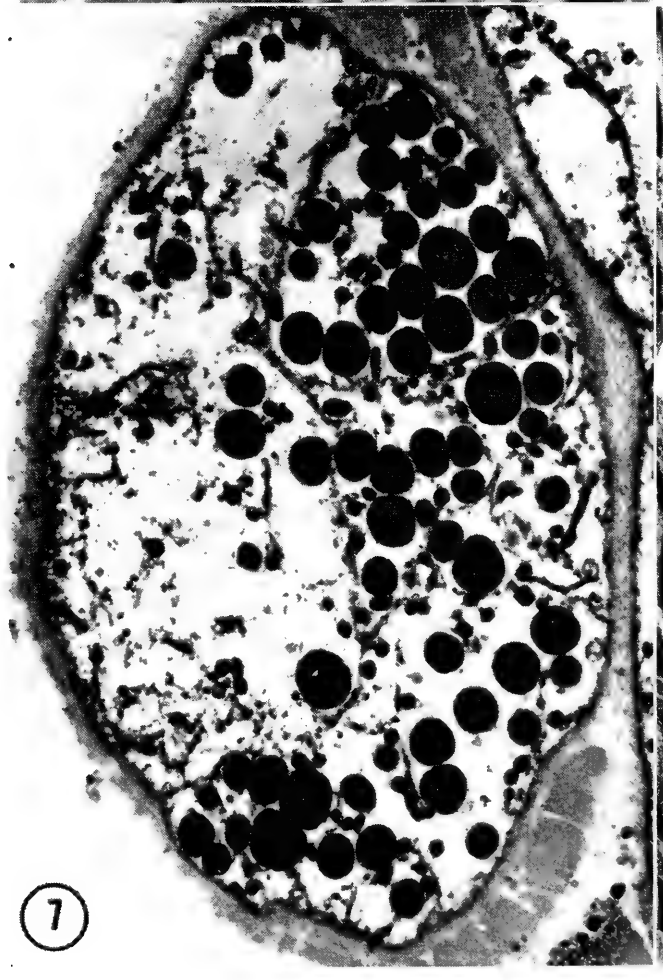

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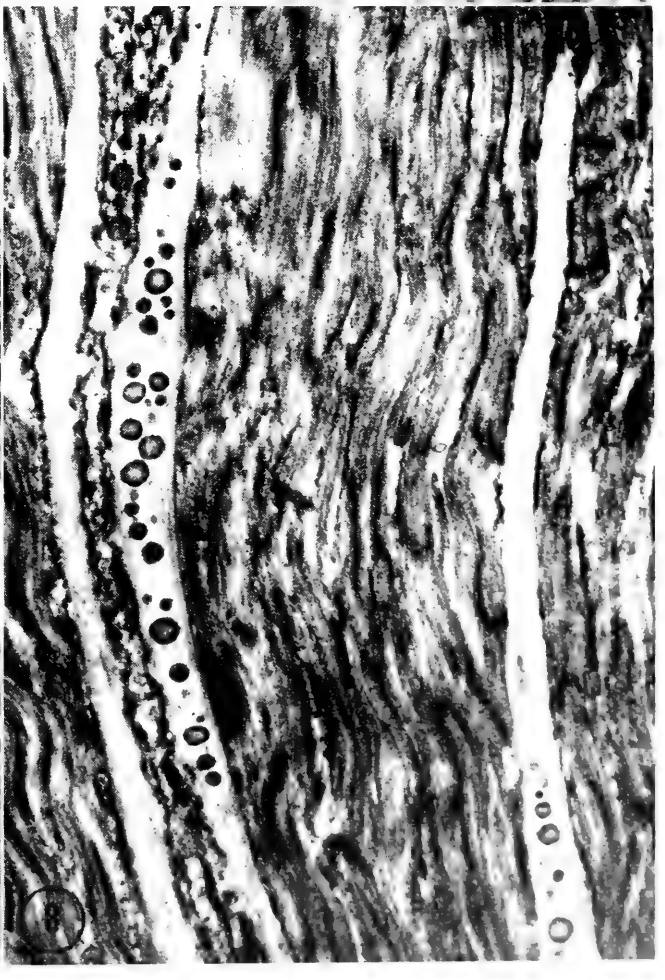

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showed no positive reaction for DNA in the giant nuclei, dermal material, or eggs of the worm. The experimental sections showed a positive reaction for the presence of DNA in the eggs of the worm. No positive reaction could be detected within the giant nuclei or dermal material even though the procedure was repeated using nuclei from several different worms. Under the present experimental conditions, these results indicate that no DNA is present within the giant nucleus of adult *Neoechinorhynchus* sp. This does not preclude the possibility that small quantities of DNA may be present at a concentration too low to be detected by this procedure. These results are in contrast to previous reports. Van Cleave (1951) reported a positive Feulgen reaction in the giant nuclei of *Neoechinorhynchus*. Marshall (1973) found the giant nuclei of larval *Moniliformis dubius* to be in a polyploidy state, and Robinson's (1973) study of the early stages of the worm support Marshall's work. The absence of DNA within the giant nuclei of *Neoechinorhynchus* sp. coupled with the complex structure present indicate that in the adult worm the giant nuclei have differentiated into unique organelles of unknown function.

With electron microscopy, as in light microscopy, the peripheral region appeared to consist of a series of lobes along the outside border of the nucleus (Fig. 3). The outermost portion of the giant nucleus appeared to be a membranous structure that separates the lobes from the dermal material of the worm. Invaginations separate the lobes forming canals that extend deep within the interior of the nucleus (Fig. 3). The outer lobes contain electron dense masses ranging from 0.7 to 3.6 μ in diameter and a fibrous background substance (Figs. 3, 4). The canals often appeared to contain small electron dense masses similar to those in the outer lobes.

Electron micrographs revealed an interesting relationship between the giant nuclei and the lacunar reservoirs. There appeared to be a layer of dermal material between the giant nucleus and the lacunar reservoir approximately 6.0 to 10.0 μ thick. Between the edge of the dermal material and the lacunar reservoir is a highly convoluted membrane (Figs. 4, 5). The lacunar reservoirs appeared to be filled with a clear background substance and a few large electron dense amorphous masses. The presence of this convoluted membrane between the lacunar reservoir and the giant nucleus indicates the possibility of a highly developed transport system involving both structures. This close relationship between the lacunar system and the giant nuclei suggests that they may act as storage depots for nutriments.

Electron microscopy of the central region revealed 2 types of structures tubular in nature, and a packed fibrous network. One type of tubular structure appeared to have a fibrous cortex and a loosely arranged medulla (Figs. 3, 6). These tubular structures contained dispersed electron dense masses 0.2 to 0.6 μ in diameter. A second type of tubular structure consisted of electron dense masses ranging from 0.2 to 1.0 μ in diameter, apparently interlaced by a network of tubules (Fig. 7). Both types of tubular structures varied in size but were consistent in their oblong shape. These structures seemed to be associated with the internal canal system that extends to the exterior of the giant nucleus. The fiber system of the central region appeared to be a packed network of fibers running parallel along a common axis (Fig. 8). Small electron dense masses and small canals were noted among the fiber network.

LITERATURE CITED

HUMASON, G. L. 1967. Animal Tissue Techniques. W. H. Freeman and Company, San Francisco, Cal. 9, 309–311 pp.

MARSHALL, J., R. N. CALL, AND W. L. NICHOLAS. 1973. A microspectrophotometric study of the DNA of the embryonic and larval nuclei of *Moniliformis dubius* (Acanthocephala). J. Parasit. 59:130–135.

ROBINSON, E. S. 1973. Growth and differentiation of giant nuclei in *Moniliformis* (Acanthocephala). J. Parasit. 59:678–684.

VAN CLEAVE. 1951. Giant nuclei in the subcuticula of the thorny headed worm of the hog (*Macracanthorhynchus hirudinaceus*). Tr. Am. Micr. Soc. 70:37–46.

Abatement of Pollution in Hite Creek, Jefferson and Oldham Counties, Kentucky[1]

Louis A. Krumholz and Stuart E. Neff
Department of Biology and Water Resources Laboratory,
University of Louisville, Louisville, Kentucky 40208

Abstract

Hite Creek, a spring-fed stream with a natural discharge that ranges from 0.2 to 75 cubic feet per second (cfs) (0.056–2.1 m^3/sec) depending on precipitation, was overwhelmed during the summer of 1970 by the constant discharge of about 1.2 million gallons per day (4.542 million liters) (about 1.9 cfs, 0.055 m^3/sec) in combined sewage and industrial wastes from a large industrial plant. That burden rendered the stream unsuitable for aquatic life and caused the waters of the stream to become a hazard to public health. In September 1970, a cease and desist order was issued against the plant, and measures were taken to divert the discharges from the plant to a new, modern sewage treatment facility under construction in the area. Concurrently, a detailed study of the physical, chemical, and biological characteristics of the stream was undertaken.

At low flow (late summer), the waste materials from the plant contributed as much as 10 times the volume of flow of the stream to the stream channel. Dissolved oxygen concentrations were extremely low, and extensive beds of sewage fungus indicated severe pollution below the points of discharge from the plant. Above those points of discharge, levels of dissolved oxygen were high and there was a normal abundance and diversity of benthic aquatic organisms. At stations downstream from the discharges, gradual recovery occurred through natural processes, and, at the mouth of Hite Creek, some 4 miles (6.4 km) downstream from the discharges, there was ample dissolved oxygen to support aquatic life, and there was a reasonably good abundance and diversity of bottom organisms, including larvae of beetles, caddisflies, midges, and other aquatic insects.

In November 1970, the sewage disposal facility began to accept all waste discharges from the plant. Winter rains flushed the stream, the sewage fungus disappeared, and the polluted areas of Hite Creek gradually became repopulated with aquatic organisms.

Since that time, the industrial plant has made extensive efforts to control all discharges from the plant into Hite Creek. By the summer of 1972, interceptors had been installed in all facilities and parking lots so that the only material that entered Hite Creek from the plant site was runoff from rainfall on completely vegetated areas of the plant property.

Introduction

Hite Creek, a small spring-fed stream that rises in northeastern Jefferson County, Kentucky, became a site of controversy in September 1970 because of pollution attributed to waste effluents that issued from the Kentucky Truck Plant of the Ford Motor Company near the source of the stream. At the suggestion of the Governor of Kentucky, we undertook a detailed study of the extent of pollution and its effects, if any, on the welfare of the stream. The Plant cooperated fully and allowed laboratory personnel free access to all parts of the stream on Plant premises to collect samples of water, bottom materials, plants, and other information germane to the study.

In 1967, when the Ford Motor Company decided to construct a major truck plant in northeastern Jefferson County, the County agreed to build a modern sewage treatment facility to satisfy the needs of the Truck Plant and any forseeable developments in that area. The Ford Motor Company agreed to pay part of the costs of construction of the facility with the proviso that it be in full operation by the time the Truck Plant went into production, or no later than 1 January 1970.

[1] Contribution No. 162 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

However, the Truck Plant went into limited production in August 1969 and reached full production early the following spring, but the sewage treatment facility did not become fully operative until November 1970. During the interim, the Metropolitan Sewer District (MSD) constructed 2 primary sewage treatment lagoons on the property of the Truck Plant to serve as a stopgap until the sewage treatment facility could be completed. The effluent from those lagoons emptied directly into Hite Creek. The total daily discharge from the Plant into the stream was about 1.2 million gallons (1.86 cfs, 0.052 m^3/sec) of effluent consisting of 800,000 gallons (3.028 million liters) of industrial wastes, 150,000 gallons (567,750 l) of domestic sewage wastes from the MSD lagoons, and about 250,000 gallons (946,250 l) of clean water as a diluent and carrier for the wastes.

That situation continued until September 1970 at which time it was obvious that Hite Creek was being overwhelmed by the discharges. Formal complaints lodged by the landowners downstream from the Plant led the State Water Pollution Control Commission to issue an order to the Truck Plant to "cease and desist" from polluting the stream. At that point (10 September 1970), our laboratory was asked to determine the extent of damage to the stream and its biota.

The Truck Plant removed the sludge from the bottom of the industrial waste lagoons so that the aerators could be operated more efficiently. All industrial wastes were retained in a temporary basin, and none entered the stream between 0800 on 12 September and 1300 on 15 September. Throughout that period, however, large amounts of clean water were released through the storm water system into Hite Creek in an effort to dilute the effluent from the sewage lagoons. On 17–19 September, a spring having a strong odor of hydrogen sulfide near the north waste lagoon was capped and a pump installed to lift the water into the lagoon.

By 1 October, the Ford Motor Company had diverted all effluents from the industrial waste lagoons through a 15-inch (38 cm) line into the permanent 24-inch (61 cm) line leading from the Truck Plant to the sewage treatment facility, and also diverted the effluents from the sewage lagoons directly into the main line, so that no such wastes entered Hite Creek at the Plant site. On 2 November 1970, The Hite Creek Sewage Treatment Plant began to accept raw sewage from the Truck Plant. In April 1971, the Metropolitan Sewer District drained the 2 sewage lagoons on the Ford property and graded and seeded the area.

During the remainder of 1971, the Ford Motor Company made concerted efforts to prevent any kinds of industrial or domestic wastes from the Truck Plant from entering Hite Creek. Curbings, interceptors, and guard posts were installed at all appropriate locations on the Plant property to prevent wastes from those areas escaping into the stream. A foam interceptor system with 3 20,000-gallon (75,700 l) holding tanks was installed to prevent any high expansion fire fighting foam from entering the storm water system and being carried into the stream. An oil interceptor adjacent to the paint and oil house dock was constructed to prevent spillage of oily products from entering the storm water system. By the end of 1971, it was obvious that the newest concepts of pollution prevention available had been put into practice.

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MATERIALS AND METHODS

Description of Hite Creek

Hite Creek rises in northeastern Jefferson County, Kentucky, as a spring about 3.2 km

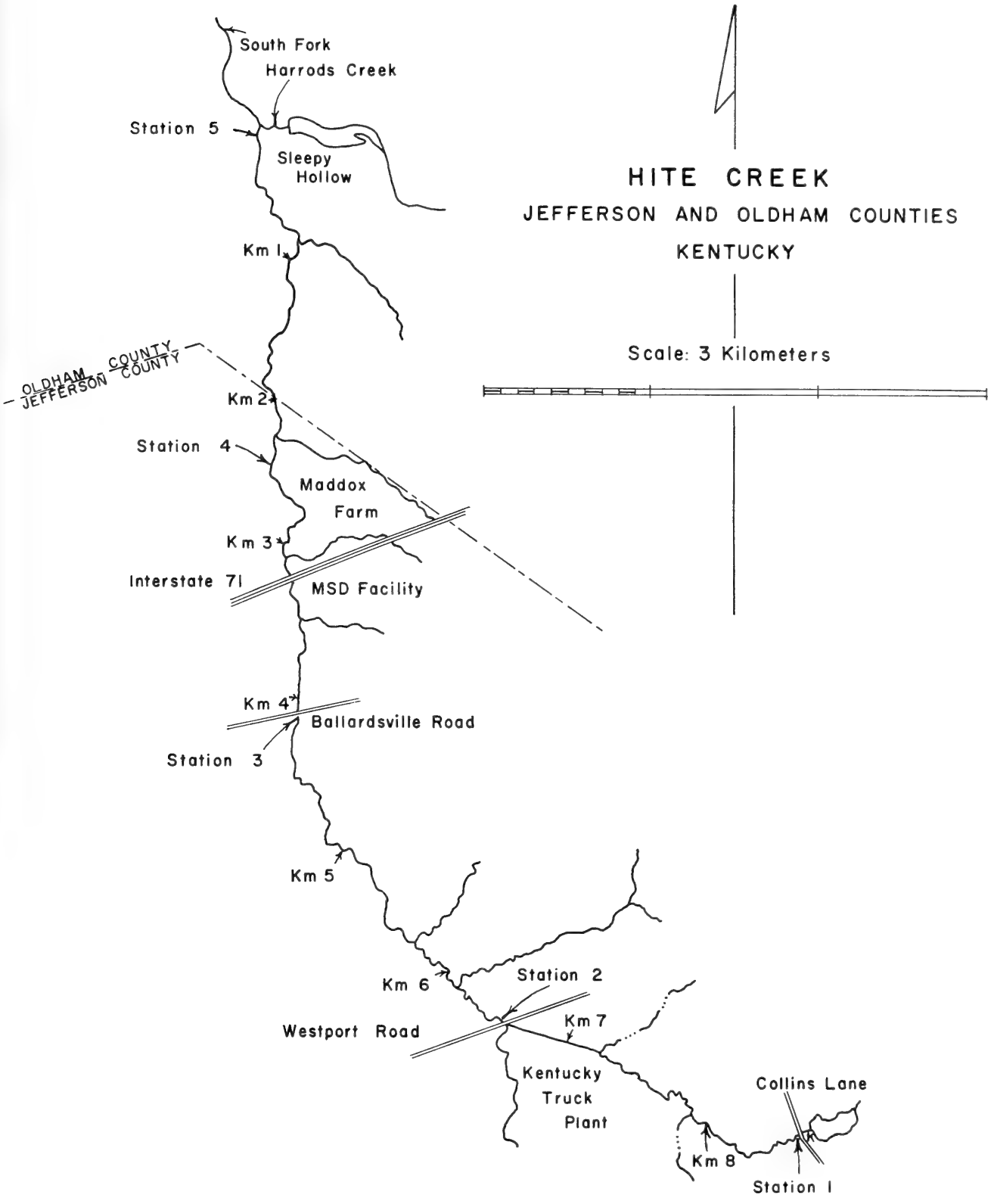

FIG. 1. Hite Creek, Jefferson and Oldham counties, Kentucky, showing stream kilometers, collecting stations, and locations of the Kentucky Truck Plant and the Sewage Treatment Plant.

north of the town of Anchorage. The water from the spring flows through a marsh literally choked with watercress (*Nasturtium officinale*) and into a small impoundment. At the outlet of the pond, where it flows through a culvert under Collins Lane, Hite Creek becomes identifiable as a stream. From that point it flows in a northwesterly direction for about 4 km over limestone bedrock and broken rubble, and then flows

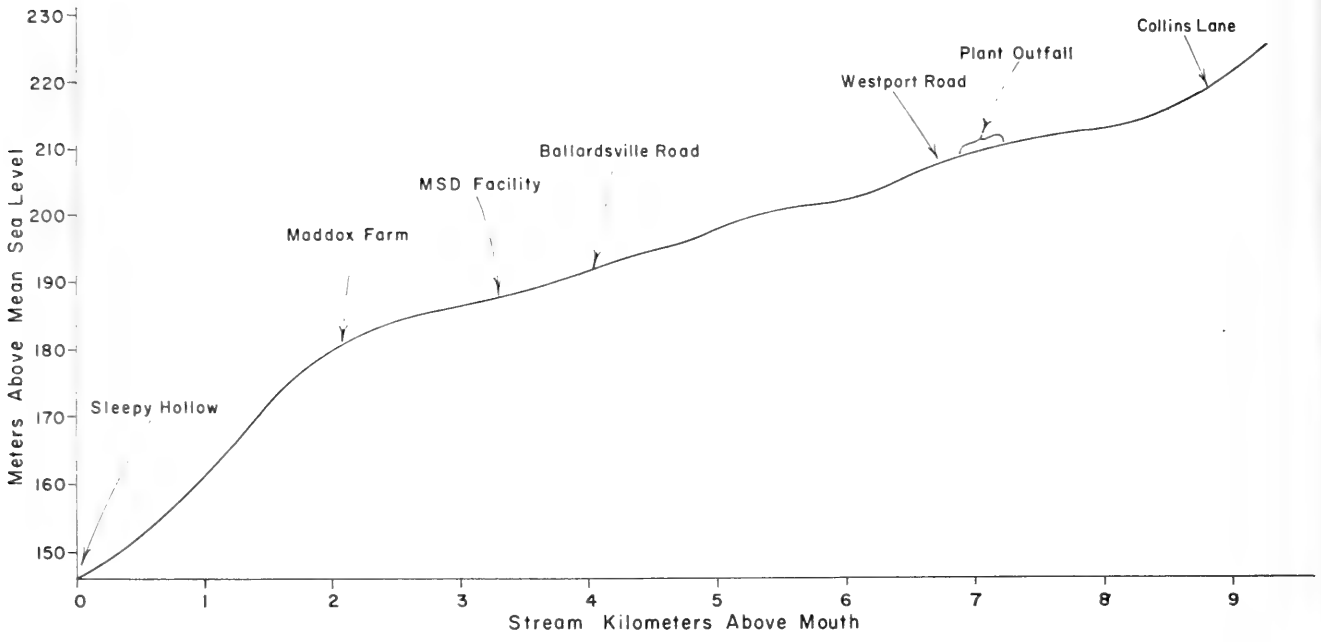

FIG. 2. Longitudinal profile of Hite Creek, Jefferson and Oldham counties, Kentucky.

due north over bedrock strata and rubble and boulders for about 4.8 km to empty into the South Fork of Harrods Creek just below the dam of Sleepy Hollow Lake in Oldham County (Fig. 1). The land through which the stream flows is gently rolling, and gradually slopes to the west as indicated by the numerous tributaries that enter the stream from the east and the essential lack of any entering from the west. In its upper 3 km the stream flows through open meadows with gently sloping banks, but as it approaches Harrods Creek the valley becomes deeply dissected with steep, heavily wooded banks nearly 60 m high.

The spring source is at an elevation of 225 m above mean sea level (msl) and empties into the South Fork at about 146 m above msl, a total fall of 79 m over its course of 8.9 km, an average fall of about 8.9 m/km (Fig. 2). Throughout its course, and particularly through its lowermost 2.4 km, the stream traverses a series of cataracts that range in height to about 1.5 m. In its upper 6.4 km, the average fall is about 6.6 m/km, whereas in the lowermost 2.4 km as it passes over the series of cataracts, the descent is about 12.7 m/km.

Near its source (Collins Lane, Fig. 1) at minimal flow, the stream is about 1.2 m wide with an average depth of about 10 cm, and has an average discharge of less than 0.055 m^3/sec. Along its course it receives several spring-fed tributaries so that at its mouth it is 3.75–4.25 m wide with pools ranging in depth to 45 cm with a discharge of about 0.1 m^3/sec following a heavy rainfall.

The Kentucky Truck Plant occupies about 200 hectares (ha) near the source of Hite Creek, entirely within the drainage basin of the stream. Of that property, about 65 ha are either under roof or are paved as parking lots or concrete ramps and runways where runoff is essentially complete. In addition, there is a test roadway about 2 km long. The remainder of the area is in permanent grassy cover or trees where runoff is minimal.

On 10, 11, 12, and 13 September 1970 the stream was cruised, particularly within the Truck Plant property, samples of water and bottom sediments were collected at various sites, and regular sampling stations were established. Major areas of pollution were below the outfalls of the industrial waste lagoons and the sewage lagoons constructed on the property by the Metropolitan Sewer District (Fig. 1). By 18 September 1970, it became obvious that regular sampling near the source of the stream and at 4 locations downstream from the outfalls would

provide adequate information on water quality and diversity and abundance of aquatic organisms on which to base sound judgments on the condition of the stream. Accordingly, each of those areas was sampled at irregular intervals for the next 15 months. A description of each area from which samples were collected follows:

Station 1.—Immediately downstream from Collins Lane (Fig. 1), the stream is about 1 m wide and 10 cm deep, the bottom is sandy with small gravel and some silt. Algal forms present were *Spirogyra* sp. and *Cladophora* sp., and the principal vascular plants were the rush *Scirpus validus*, the cat-tail *Typha latifolia*, a spike-rush (*Eleocharis* sp.), and a sedge (*Carex* sp.). The station was not shaded by trees.

Station 2.—This station was near the north edge of the Truck Plant property about 10 m downstream from the outfall of the sewage lagoons (Fig. 1). In this area, the stream had been straightened and channeled with the widening of Westport Road and was about 3 m wide and 15 cm deep. The bottom is compact clay with small slabs of broken limestone scattered over the streambed. Cat-tails and sedges were common, but the outstanding characteristic of this station was the carpet of sewage fungus (*Sphaerotilus natans*) several inches thick that completely covered the bottom and extended downstream for more than 100 m. On 3 October, this collecting site was moved downstream about 75 m to just outside the Truck Plant property to eliminate checking in and out through the security gates. The new site was just above and below Westport Road. The banks were grassy.

Station 3.—In the vicinity of the bridge for State Highway 22 over Hite Creek (Fig. 1), the stream flows due north through pastureland and ranges in width from 3 to 4 m with an average depth of 25 cm. The collecting site was about 15 m south of the bridge. The bottom was largely gravel and rubble mixed with sand and mud. The banks were lined with trees but there were no higher aquatic plants. *Spirogyra* and *Cladophora* were the dominant algae. There was no sewage fungus at this station.

Station 4.—Most samples were collected just upstream from the bridge on the dirt road leading to the Maddox farm. In that vicinity, the stream was about 3–4 m wide and 25 cm deep. The banks were heavily forested and the streambed was flat limestone bedrock with numerous small cataracts and low gravelly riffles. There were no higher aquatic plants, and, as at Station 3, the dominant algae were *Spirogyra* and *Cladophora*. Also, there was no sewage fungus at this station.

Station 5.—This station was near the bridge over Hite Creek leading to Sleepy Hollow, about 75 m upstream from the stream's confluence with the South Fork of Harrods Creek. The stream was 3–4 m wide and 20–30 cm deep with pools ranging in depth up to 50 cm. The streambed was covered with rubble and boulders interspersed with sand and gravel. The banks were heavily forested but there were no aquatic vascular plants. The rocks in the stream were covered with diatoms (unidentified) that imparted colors to the rocks ranging from bronze to deep chocolate brown. Although the same kinds of algae were present as at Stations 3 and 4, here, again, there was no sewage fungus.

Physical, Chemical, and Biological Methods

Measurements of the physical and chemical characteristics of the water were determined in the field or in the laboratory according to accepted limnological methods. Flow was measured with an Ott current meter, type 12.053; dissolved oxygen concentration was measured with a YSI Model 54 oxygen meter that had been calibrated against the azide modification of the Winkler method; specific conductivity was measured with a Beckman Model RB3 Solubridge portable conductivity meter; alkalinity was measured titrimetrically (American Public Health Association, Standard Methods) using mixed bromcresol green–methyl red indicator to a pH of 4.8 and checked potentiometrically; hardness was checked

using the EDTA titrimetric method (Standard Methods, Method B) with Hach Chemical Co., combined buffer–indicator powder; pH was read from an IL Model 175 field pH meter; temperatures were measured with a Taylor mercury stem thermometer and the above-mentioned YSI oxygen meter; chlorides were measured by Mohr titration (Standard Methods, Method C). A Perkin–Elmer Model 303 Atomic Absorption Spectrophotometer was used to determine concentrations of various cations, following procedures outlined in Perkin–Elmer Analytical Methods (1968). Concentrations of calcium were determined titrimetrically with EDTA (Standard Methods, Method C) and checked with atomic absorption. Magnesium was taken as the difference between calcium hardness and total hardness.

Square-foot samples of the bottom materials were collected with a Surber sampler at irregular intervals and were preserved in ethanol and taken to the laboratory for sorting and counting. All organisms were identified to species whenever possible, and their abundance and distribution were recorded.

Physicochemical Characteristics of Hite Creek

So far as we can determine, there is no previous information available on the physicochemical characteristics of the water in Hite Creek. We have assumed that the portion of the stream above the outfalls for the industrial and sewage wastes from the Truck Plant was not affected by those effluents or by the construction of the plant. Our first visit to the stream was on 10 September. At that time, the stream at Westport Road was highly polluted and foul smelling, obviously because of the constant flow of supernatant liquids from the sewage lagoons. Although the neutralized industrial wastes also were entering the stream, they did not appear to contribute to the odor.

When those same wastes were diverted to the unfinished sewage treatment facility on 1 October, they were released into the stream without further treatment, the net effect being to relieve about 4 km (2.5 miles) of Hite Creek (essentially from Westport Road to Interstate Highway 71) from the burden of those effluents and to shift that burden to the lowermost 3.2 km of the stream. At the same time, it provided an opportunity to study, even though for a very limited time, the sequence of events in the recovery of the stream as they took place following the sudden and complete cessation of massive pollution.

It is well known that rainfall accelerates the recovery of a stream from pollution by flushing out the watercourse and removing accumulated debris, the greater the rainfall, the greater the flushing action. In areas of continuing pollution, the rainfall also serves as a diluent, lessening the effects of pollution and ameliorating the conditions for aquatic life. During the early part of the current study period, the total rainfall was well above the average for that time of year. At Anchorage, Kentucky, (about 3.2 km south of the Truck Plant), only 0.94 cm of rain fell between 10 and 20 September, but from 21 September to 20 October, there was 17.83 cm of rain, more than twice the average for that period. If the rainfall at the Truck Plant was equivalent to that at Anchorage, a total of about 117 million liters of water fell on the 65 ha under roof or with hard surface where complete runoff is expected. In addition, there must have been some runoff from other areas following such heavy rainfall. Assuming that the total effluent of 4.65 million liters a day from the Truck Plant continued uninterruptedly for the same period, the total effluent would have been about 135 million liters. Thus, the total runoff into Hite Creek from rainfall from 21 September to 20 October probably was at least as great as the total contribution of effluents from the Truck Plant. About 10 cm of that rain fell after the effluents had been diverted from the Truck Plant to the unfinished treatment plant on 1 October.

There is a close correlation between the amount of rainfall and the turbidity of water in a stream, especially in an area where the surface of the soil has been disturbed.

TABLE 1.—WATER TEMPERATURES (C) AT VARIOUS STATIONS IN HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY, SEPTEMBER 1970 THROUGH AUGUST 1971

			Station Number				
			1	2	3	4	5
1970	11	Sep	29.0	25.9			
	12		25.0	22.0	23.0		20.0
	14		25.1	26.1	27.6		
	15		27.0	28.0	28.0	27.0	26.0
	16		28.0	28.3	27.7	26.2	23.2
	18		23.2	25.8	25.2	23.2	22.8
	21		24.1	26.2	24.8	22.3	22.2
	29		23.0	24.0	20.0	18.5	16.0
	3	Oct	17.0	17.0	18.0	17.1	15.8
	8		18.0	19.0	17.5	16.8	14.0
	14		18.0	18.5	19.5	19.0	18.0
	20		13.0	14.0	14.0	14.0	14.0
	28		14.0	13.5	14.0	15.0	14.0
	7	Nov	11.0	12.0	13.6	11.2	10.2
	12		13.0	14.5	13.5	13.5	12.5
	18		9.0	10.0	9.0	9.5	9.0
	24		3.0	3.0	2.5	2.0	1.0
	7	Dec	5.0	5.5	4.0	4.5	2.0
	15		5.0	10.5	7.0	7.5	5.0
	21		8.0	6.5	6.2	7.0	7.0
1971	21	Jan	4.0	5.0	4.0	4.0	4.0
	16	Feb		8.0	9.0		7.0
	9	Mar		8.5	7.5	7.0	6.5
	16	Apr	17.0	23.5	21.0	19.5	18.0
	24	May	17.8	25.0	23.0	21.0	20.0
	23	Jun	21.5	24.0	24.5	25.0	25.5
	27	Jul	24.0	29.5	24.0	23.0	21.0
	31	Aug	26.0	28.5	26.0	25.3	23.0

TABLE 2.—DISSOLVED OXYGEN, AS PERCENTAGE SATURATION, AT VARIOUS STATIONS IN HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY, SEPTEMBER 1970 THROUGH AUGUST 1971

			Station Number				
			1	2	3	4	5
1970	11	Sep	110.3	38.2			
	12		102.4	70.1	48.1		81.3
	14		110.8	81.4	5.2	76.5	70.8
	15		82.5	53.8	89.7	81.2	80.2
	16		76.9	30.8	77.3	82.9	87.2
	18		79.0		30.1	46.9	81.6
	21		72.6	37.0	51.6	50.8	70.6
	29		138.8	19.0	54.9	61.8	85.7
	3	Oct	125.0	158.9	107.4	34.3	77.1
	8		200	171.7	71.5	76.4	83.3
	14		86.1	91.3	89.6	81.5	92.5
	20		97.1	99.0	92.1	92.1	96.0
	28		90.2		99.0	93.0	96.1
	7	Nov	95.0	106.3	121.4	124.4	118.4
	12		119.0	104.9	123.9	116.2	86.8
	18		103.5	102.7	95.7	99.6	89.6
	24		117.3	121.8	115.6	109.5	104.9
	7	Dec	122.2	111.6	111.5	110.9	98.5
	15		121.4	107.7	120.0	118.0	98.4
	21		102.6	92.2	97.5	95.8	102.5
1971	21	Jan	106.2	101.6	100.8	95.4	101.5
	16	Feb		77.8	100.0		90.8
	9	Mar		101.7	108.0	99.2	97.9
	16	Apr	170.8	120.0	161.8	113.0	106.3
	24	May	130.2	122.2	165.2	113.9	96.0
	23	Jun	98.9	109.5	118.6	102.4	102.4
	27	Jul					
	31	Aug	116.0	144.5	145.7	97.6	90.6

On the north side of Westport Road immediately opposite the Truck Plant property, a new subdivision has been under construction since mid-1970. In that area, there has been extensive disturbance of the soil surface that is directly correlated with turbidities in Hite Creek during and following rainfall. As mentioned earlier, the upper reaches of Hite Creek within the Truck Plant property are protected by a permanent grassy cover on the watershed, and there is little siltation following even relatively heavy rainfall. Turbidities of the water in Hite Creek in that area ranged from 0.2 to 39 mg/l of silicon dioxide for an average of about 14.5 mg/l. At Station 2, just below Westport Road, the range in turbidity was from 0.2 to 252 mg/l with an average of 28.5 mg/l, and at Stations 3, 4, and 5, the ranges were from 1.25 to 295, 3.1 to 178, and 2.9 to 233 mg/l, respectively, with respective averages of 30.3, 24.6, and 26.2 mg/l. From this information, it appears that the primary cause of turbidity in Hite Creek originated from construction taking place outside the Truck Plant property.

Water temperatures in Hite Creek mirrored the seasonal air temperatures throughout the study (Table 1). Although the principal source of the stream is a spring, a small impoundment near the source has an ameliorating effect on water temperature. In this study, we considered the outlet of that pond at Collins Lane as the source of Hite Creek (Station 1, Fig. 1). As in most streams, temperature was not a limiting factor; the range for all measurements recorded during the study was from 1.0 C in late November 1970 to 29.5 C in July 1971.

TABLE 3.—CONDUCTIVITY (MHOS) OF WATER AT VARIOUS STATIONS IN HITE CREEK, JEFERSON AND OLDHAM COUNTIES, KENTUCKY, SEPTEMBER 1970 THROUGH AUGUST 1971

			Station Number				
			1	2	3	4	5
1970	11	Sep	250				
	12		370	510	720		880
	14		260	430	320		
	15		355	620	190	420	220
	16		330	750	700	520	400
	18		360		890	820	750
	21		100	750	570	680	780
	29		230	920	450	540	720
	3	Oct	380	500	490	950	850
	8		245	190	310	740	1100
	14		315	340	275	275	360
	20		350	118	220	350	410
	28		385	250	295	580	450
	7	Nov	395	450	425	600	620
	12		400	360	440	575	725
	18		395	405	410	615	570
	24		385	375	370	415	420
	7	Dec	390	380	340	750	520
	15		380	390	420	750	690
	21		355	190	180	235	235
1971	21	Jan	350	350	325	510	550
	16	Feb		725	550		440
	9	Mar		330	335	520	470
	16	Apr	310	370	295	850	750
	24	May	340	425	265	675	590
	23	Jun	370	350	395	675	575
	27	Jul	400	400	360	590	680
	31	Aug	370	280	360	900	775

TABLE 4.—BICARBONATE ALKALINITY (MG/1) OF WATER AT VARIOUS STATIONS IN HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY, SEPTEMBER 1970 THROUGH AUGUST 1971

			Station Number				
			1	2	3	4	5
1970	11	Sep	108	82			
	12		147	129	106		136
	14		156	118	122		
	15			96	128	137	122
	16		178	120	136	129	128
	18		168		134	172	143
	21		196	106	152	164	150
	29		175	140	152	176	162
	3	Oct	112	172	148	178	170
	8		160	62	114	127	110
	14		184		122	124	130
	20		167	42	72	101	110
	28		188	118	121	119	110
	7	Nov	190	180	182	174	182
	12		190	168	182	160	161
	18		192	177	170	150	162
	24		164	151	155	143	164
	7	Dec	170	145	142	146	160
	15		186	172	166	178	149
	21		164	80	62	74	84
1971	21	Jan	156	147	138	136	133
	16	Feb		87	100		129
	9	Mar		123	122	122	130
	16	Apr	138	120	110	180	136
	24	May	143	111	102	107	125
	23	Jun					
	27	Jul	175	155	162	143	123
	31	Aug	169	100	134	98	122

Even though temperature itself was not a limiting factor, the influence of temperature on dissolved oxygen in water is important. The solubility of atmospheric oxygen in fresh waters ranges from 14.6 mg/l at 0 C to about 8 mg/l at 30 C. Still, the salubrious effect of lower stream temperatures, the continuing agitation and mixing of the water by the current, and the turbulence provided by the many small cataracts in Hite Creek tend to assure dissolved oxygen values close to or in excess of saturation (Table 2). Our observations in Hite Creek indicate that there were satisfactory concentrations of oxygen at all times in the stream above the Truck Plant. However, in the area below the discharges of sewage and industrial wastes prior to 1 October, there was a marked depletion of dissolved oxygen to as little as 19 percent saturation (1.6 mg/l) on 29 September (Table 2). Once those wastes were diverted, there was a marked resurgence of dissolved oxygen at Stations 2 and 3, between the Truck Plant and the new facility, with a continued depression at Stations 4 and 5 below the new facility where the untreated wastes entered the stream. Again, as soon as the new sewage treatment facility began to process the wastes early in November, there was a dramatic increase in dissolved oxygen at Stations 4 and 5, and those high levels persisted at all stations for the remainder of the study.

Hydrogen ion concentrations (pH) were slightly alkaline at all stations and ranged from 7.2 to 8.9 throughout the study.

Conductivities (total electrolytes or total ions) showed expected values for streams of the region (Table 3). The increase in elec-

TABLE 5.—RANGES AND AVERAGE CONCENTRATIONS OF MAJOR CATIONS AND CHLORIDES AT VARIOUS STATIONS IN HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY

	Station Number				
	1	2	3	4	5
Calcium					
Range	8.6–17.7	18.2–52.5	19.2–64.9	22.1–67.9	18.8–62.5
Average	14.8	35.6	37.5	45.6	44.7
Magnesium					
Range	10.9–20.9	10.6–22.3	9.2–24.1	5.8–20.7	11.0–23.1
Average	15.4	14.9	15.2	14.0	15.1
Iron					
Range	0.00–0.78	0.04–5.26	0.05–10.18	0.02–4.65	0.05–5.35
Average	0.24	0.64	0.93	0.58	0.52
Manganese					
Range	0.02–0.44	0.00–1.41	0.00–2.05	0.00–2.44	0.01–0.18
Average	0.19	0.37	0.44	0.35	0.07
Potassium					
Range		1.01–3.32	1.22–3.44	2.40–6.33	2.01–7.88
Average		1.68	2.12	4.03	3.87
Copper					
Range		0.00–0.07	0.00–0.10	0.00–0.10	0.00–0.14
Average		0.02	0.03	0.04	0.04
Chloride					
Range		3.6–175.3	4.2–90.9	8.5–290.0	9.7–231.5
Average		27.9	19.5	106.9	90.2

trolytes below the outfalls of the Truck Plant during September 1970 is not surprising, particularly in light of the fact that the effluents from the industrial waste lagoons comprised more than two-thirds of the total discharge of the stream at that time. Those wastes contained many electrolytes that had been brought to neutral hydrogen ion concentration by buffering prior to discharge. As with dissolved oxygen, the diversion of all wastes to the sewage treatment facility on 1 October merely transferred the burden downstream, and the high values at Station 2 in September became manifest at Station 4 thereafter (Table 3). The high value for conductivity at Station 2 on 16 February 1971 was traceable to a special incident. Following a heavy snowfall, the Truck Plant used about 20 tons of salt (sodium chloride) to aid in snow and ice removal from some ramps and roadways. As the snow melted, it carried the salt into the stream.

Bicarbonate alkalinity at the source of Hite Creek (Station 1, Table 4) ranged from 112 to 217 mg/l during the study period, with an average value of 169 mg/l. These values are within the normal range of alkalinity for streams in the region. The values for stations farther downstream showed rather wide variations, and reflected the influence of effluents from the Truck Plant. On some occasions, those effluents contained rather concentrated chemical wastes, at other times, they were primarily large discharges of clean water used as a diluent. After the new treatment plant became operative early in November 1970 and began processing all waste materials from the Truck Plant, the fluctuations became of lesser magnitude (Table 4).

Since Hite Creek is a limestone stream, it was expected that the calcium carbonate hardness was moderately high and within the usual range for other streams in the region. As with the other chemical parameters, the effects of dilution following rainfall were readily manifest. The relatively

low values for hardness on 8 and 20 October, along with those on 21 December, were directly correlated with heavy rainfalls at those times.

Each of the major cations, calcium, magnesium, iron, manganese, and potassium were present in amounts comparable to those of other limestone streams in the region (Table 5). Total iron was most abundant during periods of high discharge and reflected the iron suspended in sediments, particularly in samples collected on 8 and 20 October. Samples analyzed for zinc revealed that concentrations ranged from 0 to 0.12 mg/l, but in most samples the amounts were so small as to be barely detectable.

Among the anions, chlorides showed the greatest range of concentration (Table 5). As mentioned earlier, the single high value at Stations 2 and 3 resulted from salting ramps and runways following a heavy snowfall in February 1971. The high values at Stations 4 and 5 did not become manifest until the sewage treatment plant became operative and began chlorination of wastes in November 1970. Prior to that time, chlorides were relatively low throughout the stream. Sulfates were fairly high early in the study period probably because of the industrial wastes issuing from the Truck Plant, but dropped markedly as soon as the treatment plant was in full operation. Nitrates, nitrites, and phosphates were within the expected ranges for limestone streams of the region throughout the study period.

Biological Characteristics of Hite Creek

The numbers and kinds of organisms in a stream community usually indicate the quality of living conditions, and provide a sound basis for assessing the extent of degradation of the environment long after the physical and chemical causes of the degradation have disappeared (Hynes 1960, 1970). These organisms can also document the recovery of the stream from environmental insult. Some organisms are quite tolerant to low concentrations of dissolved oxygen while others may require levels near saturation. Some insect larvae are quite tolerant to relatively high levels of organic pollution, others may demand clean waters for their livelihood. Accordingly, much time and effort was expended in obtaining adequate samples of the different organisms at all stations in Hite Creek so that changes in the populations could be documented.

From the beginning of the study, it was readily obvious that the upper reaches of the stream were not polluted. There may have been minimal effluents from the farm property near the spring source, but any untoward effects would have been ameliorated as the water passed through the small impoundment just outside the property of the Truck Plant. Below the effluents from the industrial waste and sewage lagoons, it was obvious that there was gross pollution of the stream.

On 11 and 12 September, 2 square-foot bottom samples were collected at Stations 1, 2, 3, and 5 and just below the outfall from the industrial waste lagoons. In those collections, the kinds and numbers of aquatic animals present upstream from the point where the first effluents from the Truck Plant entered the stream were about as expected for that size stream at that time of year (Table 6). There were no such organisms in the stream below the outfall of the industrial waste lagoons, and only relatively few at Station 2. At Station 3, however, the effects of the effluents had been ameliorated to some extent and the stream had recovered sufficiently to support large numbers of midges and black flies that feed primarily on detritus or particulate matter, an indication that the stream was beginning to to assimilate the materials that entered some distance upstream. The numbers and kinds of organisms collected at Station 5 reflect the more diverse nature of the stream substrate made up of stones and rubble and a much more stable community of aquatic organisms.

At Station 1, all but one of the 10 major groups of organisms listed in Table 6 were represented, and in addition there was an abundance of freshwater sponges, an indication of relatively high quality water. Also

TABLE 6.—NUMBERS OF SPECIES AND INDIVIDUALS OF BOTTOM ORGANISMS TAKEN IN BOTTOM SAMPLES AT DIFFERENT STATIONS IN HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY, 11 AND 12 SEPTEMBER 1970. STATION 1-D WAS IMMEDIATELY BELOW THE OUTFALL OF THE SEWAGE LAGOONS

	Station 1		Station 1-D		Station 2		Station 3		Station 5	
	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms
Diptera	2	195	0	0	3	8	2	48	3	23
Trichoptera	3	253	0	0	1	6	0	0	1	1
Ephemeroptera	1	143	0	0	0	0	1	3	0	0
Megaloptera	1	1	0	0	0	0	0	0	0	0
Odonata	1	1	0	0	0	0	0	0	0	0
Hemiptera	1	1	0	0	1	1	0	0	1	1
Coleoptera	1	12	0	0	0	0	1	2	1	1
Mollusca	1	16	0	0	0	0	0	0	0	0
Other	1	10	0	0	0	0	0	0	1	3
Totals	12	632	0	0	5	15	4	53	7	29

at that station there were more different species of organisms than at any other station indicating a relatively high diversity and a well-balanced community. Just below the outfall of the sewage lagoons, the unbroken carpet of sewage fungus showed beyond doubt that the materials issuing from those lagoons was the primary source of organic pollution in Hite Creek. That kind of bacterial growth develops best in running waters where it feeds principally on organic matter, particularly carbohydrates. But it also requires large quantities of nitrogen that it obtains from both organic and inorganic sources. As soon as the effluents from the sewage lagoons were diverted on 1 October, the bacterial carpet began to disintegrate and had completely disappeared within 2 weeks. At Station 2, 5 of the 10 major groups were represented by 7 species and a total of 30 individuals. The most numerous were members of the more tolerant midges. At Station 3, 7 of the 10 major groups were represented by 11 species among which the midges and blackflies were most numerous, but there were relatively large numbers of snails and some dragonfly larvae. At Station 4, only 6 of the 10 groups were represented by 8 species, but as mentioned previously, the gradient of the stream and the resulting substrate at that station precluded the oc-

TABLE 7.—NUMBERS OF SPECIES AND INDIVIDUALS OF BOTTOM ORGANISMS TAKEN IN BOTTOM SAMPLES IN HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY, DURING OCTOBER 1970

	Station 1		Station 2		Station 3		Station 4		Station 5	
	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms
Diptera	3	43	1	130	5	106	4	725	3	1069
Trichoptera	1	6	0	0	0	0	0	0	1	108
Ephemeroptera	2	2	0	0	0	0	1	1	2	36
Megaloptera	0	0	0	0	0	0	0	0	0	0
Odonata	0	0	0	0	1	1	0	0	0	0
Hemiptera	2	2	0	0	0	0	0	0	1	1
Coleoptera	1	10	0	0	1	1	0	0	1	1
Plecoptera	0	0	0	0	0	0	0	0	0	0
Oligochaeta	1	18	1	540	1	126	1	11	0	0
Mollusca	3	60	0	0	2	69	2	258	1	1
Crustacea	4	151	0	0	1	11	4	146	1	1
Other	1	1	0	0	0	0	0	0	0	0
Total	18	293	2	670	6	314	12	1141	10	1217

TABLE 8.—SURVEY OF HITE CREEK, JEFFERSON AND OLDHAM COUNTIES, KENTUCKY. NUMBERS OF SPECIES AND INDIVIDUALS TAKEN IN BOTTOM SAMPLES FROM NOVEMBER 1970 TO SEPTEMBER 1971

	Station 1		Station 2		Station 3		Station 4		Station 5	
	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms	No. of Species	No. of Organisms
Diptera	5	835	7	826	7	241	8	955	6	581
Trichoptera	1	20	1	1	1	5	2	14	1	116
Ephemeroptera	2	28	2	3	2	7	1	10	2	18
Megaloptera	0	0	0	0	0	0	1	1	1	3
Odonata	2	2	0	0	0	0	1	1	0	0
Hemiptera	0	0	0	0	0	0	0	0	0	0
Coleoptera	3	6	2	4	2	2	4	5	5	14
Plecoptera	0	0	0	0	1	1	0	0	2	3
Oligochaeta	1	89	1	1177	1	1018	1	64	1	10
Mollusca	3	5	1	1	3	86	3	236	1	1
Crustacea	4	132	0	0	1	2	0	0	4	7
Other	0	0	0	0	0	0	1	2	0	0
Total	21	1117	14	2012	18	1362	22	1288	23	753

currence of organisms adapted to living in silty, sandy, or gravelly bottoms.

It is well documented in the literature that streams rapidly regain populations of bottom dwelling organisms when pollution is abated, thereby reestablishing the complex foodwebs that make up a healthy stream community. It is also well known that rainfall accelerates the recovery of a stream from pollution by flushing out the watercourse and removing accumulated debris and making the stream more amenable to occupancy by the bottom fauna. However, the establishment of populations of bottom organisms depends to a great extent on a favorable reproductive season. With the diversion of waste effluents from the Truck Plant to the sewage treatment facility on 1 October followed by heavy rainfall, that portion of Hite Creek between Stations 2 and 4 began to recover. Although there are no great differences in the kinds or organisms collected in September and October from various stations in Hite Creek (Tables 6, 7), the stage had been set for the rejuvenation of the populations of bottom organisms.

Collections of bottom organisms were continued until September 1971 and there was a dramatic resurgence of the numbers and kinds of animals, especially in the area immediately below the Truck Plant (Station 2, Table 8), following the diversion of the waste discharges. In October 1970 (Table 7), only 2 of the most tolerant forms were found whereas in the following 10 months there were indications that at least 14 kinds of organisms were establishing colonies. The abundance of oligochaetes at Station 2 were indicative of the lingering effects of the earlier pollution, but by September 1971, most of those had disappeared.

Preliminary sorting of our collections from Hite Creek included at least 57 different kinds of bottom organisms as follows: 1 planarian, 1 or more tubificids, 1 leech, 2 isopods, 2 amphipods, 1 crayfish, 4 snails, 1 fingernail clam, and 44 different kinds of insects (2 stoneflies, 4 mayflies, 2 damselflies, 6 dragonflies, 3 hemipterans, 1 megalopteran, 4 caddisflies, 14 true flies, and 8 beetles). In all likelihood, other kinds of invertebrates are present in the stream or will become established as environmental conditions continue to improve.

Streams as small as Hite Creek do not ordinarily support extensive fish populations, but during the course of our investigation we collected 3 kinds of minnows, the stoneroller *Campostoma anomalum*, the river shiner *Notropis blennius*, and the common shiner *Notropis cornutus*; 3 kinds of sunfishes, the bluegill *Lepomis macrochirus*, the longear sunfish *Lepomis megalotis*, and the largemouth bass *Micropterus salmoides*; the blackstripe topminnow *Fundulus no-*

tatus, and the black bullhead *Ictalurus melas*.

DISCUSSION

This study provided an opportunity to document the sequence of events in Hite Creek while the stream was overwhelmed by industrial and domestic wastes and following the abatement of that pollution. The changes in the physical and chemical characteristics of the water as soon as the wastes from the Truck Plant were diverted to the sewage treatment facility provided an early indication that the quality of the water underwent a sudden and dramatic improvement. Populations of aquatic insects became reestablished very quickly when enviromental conditions became suitable.

Even though aquatic insects contribute a major portion to the assemblage of bottom organisms, there are a great many other invertebrates that perform a relatively important role in the functioning of the stream ecosystem as outlined by Krumholz and Neff (1970), Macan (1963), Coker (1954), Hynes (1960, 1970), and many others. In a stream like Hite Creek where there has been a gross insult to the environment followed by an abrupt cessation of that insult, it is difficult to evaluate the changes as they occur and to predict the time required for the reestablishment of all segments of the biota. Many workers have pointed out the difficulties in adequately sampling bottom fauna (Macan 1958, 1961; Hynes 1960; Cummins 1962; Armitage 1961; Elliott 1967; Minshall 1968; Minckley 1963; Nielsen 1950, and others). In the present study, only selected sites were sampled routinely and it is quite likely that many kinds of organisms not reported here live and thrive in Hite Creek, and will continue to do so as long as conditions remain favorable.

In spite of the paucity of data gathered from the limited number of sampling sites, it is obvious from the data in Tables 6, 7, and 8 that Hite Creek was well on its way to recovery within a year following the abatement of pollution. In many ways, Hite Creek is typical of small streams throughout the nation that have been the recipients of noxious wastes. We believe that most such streams can recover, at least partially, to their former states when pollution is abated.

LITERATURE CITED

AMERICAN PUBLIC HEALTH ASSOCIATION. 1971. Standard methods for the examination of water and wastewater. Thirteenth edition. Washington, D.C. 874 pp.

ARMITAGE, K. 1961. Distribution of riffle insects of the Firehole River, Wyoming. Hydrobiologia 17:152–174.

COKER, R. E. 1954. Lakes, Streams, Ponds. Univ. N. Carolina Press, Chapel Hill, N.C. 347 pp.

CUMMINS, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Amer. Midl. Nat. 67(2):477–504.

ELLIOTT, J. M. 1967. Invertebrate drift in a Dartmoor stream. Arch. Hydrobiol. 63:202–237.

HYNES, H. B. N. 1960. The biology of polluted waters. Liverpool Univ. Press, Liverpool, England. 202 pp.

———. 1970. The biology of running waters. Liverpool Univ. Press, Liverpool, England. 555 pp.

KRUMHOLZ, L. A., AND S. E. NEFF. 1970. The freshwater stream, a complex ecosystem. Water Resources Bull. 6(2):163–174.

MACAN, T. T. 1958. Methods of sampling the bottom fauna in stony streams. Mitt. int. Ass. theor. appl. Limnol. 8:1–21.

———. 1961. A review of running water studies. Verh. int. ver. Limnol. 14:587–602.

———. 1963. Freshwater Ecology. John Wiley & Sons Inc. New York, N.Y. 338 pp.

MINCKLEY, W. L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildl. Monogr. No. 11:1–124.

MINSHALL, G. W. 1968. Community dynamics of the benthic fauna of a woodland springbrook community. Hydrobiologia 32:305–339.

NIELSEN, A. 1950. The torrential invertebrate fauna. Oikos 2:176–196.

PERKIN-ELMER CORPORATION. 1968. Analytical methods for atomic absorption spectrophotemetry. Lombard, Illinois. Looseleaf manual.

NEWS AND COMMENT

The Kentucky Junior Academy of Science 1974–1975

In 1974, The Kentucky Junior Academy of Science sponsored 3 major events for the student membership: a statewide talent search, the second KJAS Spring Symposium, and a series of regional seminars that met concurrently in the late fall.

The symposium was held in April at Transylvania University, Lexington. Fifty-one papers were presented in areas of the biological and physical sciences. The natural sciences were divided into 8 sections for the symposium: animal physiology, behavioral science, biochemistry and medicine, botany, chemistry, ecology and earth science, microbiology, and physics. The physics section had the most participation with 10 papers presented.

Students in each section presented their papers before a panel of judges, and a cash award of $30.00 was presented to the author of the best paper in each section; second and third prizes received $10.00 each. The first prize winners in each section were:

Animal Physiology	P. C. Wagner, Waggener High, Louisville
Behavioral Science	John Meisenheimer, Jr., Model Laboratory, Richmond
Biochemistry and Medicine	Joy Arnold, Owen County, Owenton
Botany	Suzie Yaste, Marion County, Lebanon
Chemistry	Evelyn Goodin, Marion County, Lebanon
Ecology and Earth Science	Connie Mitchell, Augusta High, Augusta
Microbiology	James Harris, Model Laboratory, Richmond
Physics	Terry Rogelstad, Warren East, Bowling Green

Francis Ballard, Marion County High School, won the state science talent search award of $75.00. Her paper, entitled "Noise Pollution," was entered in the nationwide Westinghouse Science Talent Search. The winner of the 1975 State Talent Search will be announced at the spring meeting in April.

This was the second consecutive year that KJAS sponsored a spring symposium. Hopefully, attendance and participation will continue to increase along with an improvement in quality of papers.

Clubs belonging to KJAS now receive a cash award of $40.00 for the best scrapbook of club activities with the award going to the club with the best presentation and the most activities. Evarts High School's club (Harlan County) received the 1974 award at the spring meeting.

For the academic year 1974–1975, KJAS awarded $248.00 in research grants to students from 7 senior high schools. In the fall, KJAS members submitted research proposals to a selection committee of KAS members. A total of 18 proposals was submitted with 7 students receiving individual grants ranging from $19 to $50. This financial support will be used to purchase equipment, travel to college libraries and laboratories, and as travel funds for field work. Recipients are expected to report their results or make a progress report in the 1975 symposium.

In December 1974, KJAS sponsored a one-day seminar with the theme, "Natural Resources of Our Kentucky." The seminar was held at 7 institutions over Kentucky, viz., Alice Lloyd College, Eastern Kentucky University, University of Louisville, Morehead State University, Murray State University, Thomas More College, and Western Kentucky University. Students and teachers from all secondary schools in the state were invited to participate with the KJAS mem-

bership. Each seminar dealt with regional problems on land use, endangered habitats and species, and the use and abuse of other regional resources. At each institution, KAS members presented talks or led discussions to provide general information in these problem areas and point out possible research projects that could be conducted by individual students, teachers, or science clubs. A total of 40 schools and more than 380 students and teachers attended these programs. This attendance figure is one of the largest ever for a KJAS-sponsored activity. Hopefully, the meetings generated interest and enthusiasm that will be translated into activities designed to investigate our natural resources at a regional level.

The 1975 symposium will be held Saturday, 26 April at The Centre College of Kentucky, Danville. KAS members are urged to participate as judges if they are contacted by a KJAS representative.

Present membership in the Junior Academy stands at 38 clubs and 4 individual members. Four new clubs added this year are Russellville High School in Russellville, Madison (Co.) Central in Richmond, Lloyd Memorial in Erlanger, and St. Mary's in Paducah. In recent years, club membership has been increasing at an annual rate of 10 percent. For the ecologists, geographers, and demographers, this rate represents a doubling time of 7 years! In this case, growth is slow when one realizes that there are over 300 senior high schools in the state!

The elected officers of KJAS are an asset to the organization and they have been quite active in its activities. The officers for 1974–1975 are:

President—Ray Hislope, Marion County High School

Vice-President—Joy Arnold, Owen County High School

Secretary—Connie Mitchell, Augusta High School

William H. Martin, Director
Eastern Kentucky University

Report from the Kentucky Task Force on Public Science and Technology

Background and Aims

In 1973, the Kentucky Science and Technology Commission joined with the Kentucky Academy of Science in a statewide study of the status of science and technology. This study has been carried out principally by 2 task forces. The Task Force on Private Science and Technology, under the direction of Mr. Charles Hoertz of Ashland Oil, has undertaken a study of the private sector. This is a summary report of the second task force, the Task Force on Public Science and Technology concerned with public sector aspects, under the direction of Dr. William G. Lloyd, Department of Chemistry, Western Kentucky University.

Our general mandate was described by Damon Harrison, Commissioner of Commerce and Chairman of the Science and Technology Commission, in these words: "As a starter, we need to document Kentucky's current scientific and technological resources and to find ways to better utilize these resources to solve problems and stimulate growth." Our efforts have been coordinated by Dr. Marvin W. Russell, Past President of the Kentucky Academy of Science and a member of the Kentucky Science and Technology Commission.

The Main Projects

Four main projects have been undertaken by groups of task force members:

Kentucky's Needs in the Area of Public Science and Technology. This study, conducted in 1973, required development of a questionnaire in which the questions were nondirective. Each respondent was also asked to spell out 'the one or two most important problem areas which might be helped by the better application of science and technology in the public sector'. About 600 questionnaires were sent out to 6 groups of respondents: members of the Kentucky legislature, state agency supervisors and technical people (drawn mainly from de-

partments with responsibilities of a technological nature), municipal and county technical people (engineers, agricultural agents, public health official), academic scientists and engineers (every thirtieth name on an alphabetical list), scientists and engineers in private industry (a list provided by our sister task force), and a group representing the general public. Responses have been analyzed in detail in a 42-page report entitled 'Kentucky Needs in the Area of Public Science and Technology'. This study was carried out by Donald Rowe and William Lloyd.

The 1974 Kentucky Scientific Manpower Registry. A simple questionnaire identifying areas of scientific and technological expertise was developed and sent to every academic scientist and engineer in the state. Instead of making our own analysis of what seemed important to us from these returns, the task force has done something we hope will be of greater value: it has placed this information in the state computer system and has developed a simple search system (the SMART system, Scientific Manpower Access–Retrieval) which permits fast searches for individuals possessing any particular scientific of engineering expertise, or expertise in any combination of fields, or any combination of expertise with geographic area, institutional affiliation, degrees held, research activity, or any of several other characteristics. Searches can be run from any terminal of the state computer system. A 33-page manual has been written, explaining in detail how to use this system: The 1974 Kentucky Scientific Manpower Registry: Manual for the SMART Access–Retrieval System. This manual was prepared by Michael Furlong and William Lloyd.

Scientific Dissertations and Theses in Kentucky Since 1950. The most neglected of all the scientific resources in this or any state has been the academic dissertation. In Kentucky alone, since 1950, thousands of man-years have been spent in painstaking observation and interpretation of scientific and engineering data. The reason for ignoring this mine of information is easy to grasp: those involved in research and development studies, whether in the public or the private sectors, have no quick and easy way to find out if and where there may be dissertations in areas of relevance to present problems. Borrowing heavily from the programming of the manpower registry described above, the task force has created a START (Scientific Thesis Access–Retrieval) index which now contains over 4700 scientific and engineering dissertations and theses, from 1950 through 1973. Dissertation titles can be located by a simple computer search query, according to specialty or a combination of specialties, using other optional criteria such as institution, author name, degree level, or year of degree. These searches can be made from any terminal of the state computer system. A 30-page manual has been written, explaining what can be gotten from the START index and how to do it: Scientific Dissertations and Theses in Kentucky, 1950–74: Manual for the START Access-Retrieval System. The manual was prepared by Michael Furlong and William Lloyd.

Federal R&D Funding in Kentucky. The bulk of research and development funding of academic institutions and nonprofit institutes, and an important part of industrial R&D funding, comes from 9 departments and agencies of the federal government. A study of Kentucky's general scientific and technological capabilities, vis a vis those of neighboring states and those elsewhere in the nation, has been made with special reference to federal R&D funding in recent years. All data used are from federal agency reports. Kentucky, according to a number of criteria, ranks as 'adequate' to 'very good'. The one area in which, year after year, Kentucky has ranked very low, is in the share of federal R&D dollars spent here. A 45-page report of this study has been prepared: Federal R&D Funding in Kentucky. This study was made by William Lloyd.

Reports Available

The 4 major reports of the task force, noted above, have been published. Persons desiring a copy of any of these reports should write or call:

Mrs. Ann M. Badham
Kentucky Department of Commerce
Capitol Plaza Building
Frankfort, KY 40601
(606) 564-4270

In addition to these reports, Mr. Russell Powell of the University of Kentucky, under the joint sponsorship of both task forces, has prepared a detailed report on scientific and technological book and journal holdings in public and private libraries throughout the state. Copies of this report may also be obtained through Mrs. Badham at the above address.

The Task Force on Public Science and Technology has now completed its mission. It is our hope that these studies will prove useful to Kentucky's growing research and development community, and to others concerned with the development of our state's scientific and technological potential.

William G. Lloyd
Task Force Director

Standing Committees The following persons have been appointed to Standing Committees of the Academy by President Ellis V. Brown:

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Joseph Hendon	1977	Murray State University—Chairman
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Amiya Mohanty	1976	Eastern Kentucky University

Legislation

Marvin Russell	1975	Western Kentucky University—Chairman
Harold Eversmeyer	1976	Murray State University
William Lloyd	1977	Western Kentucky University and University of Kentucky

Distribution of Research Funds

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Jerry Howell, Jr.	1977	Morehead State University

Publications

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Varley E. Wiedeman (Assoc. Editor)

William F. Wagner	1975	University of Kentucky
J. Hill Hamon	1975	Transylvania University
G. E. McClellan	1977	Murray State University

Annual Meeting The Annual Meeting of the Academy is scheduled for 7–8 November 1975 at the Health Sciences Center of the University of Louisville. Charles E. Kupchella and John R. Meyer will serve as co-hosts.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and, once accepted, an attempt will be made to publish papers in the order of their acceptance. Manuscripts should be typed, double spaced throughout, on good quality white paper 8½ × 11 inches (216 × 279 mm). The original and one copy should be sent to the Editor and the author should retain a copy for his own use in correcting proof. Metric and Celsius units are to be used for all measurements instead of, or in addition to, English and Fahrenheit units. Format and style may vary somewhat depending on the scientific discipline, but the basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of papers in the Journals of the American Chemical Society, the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and A Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined.

The sequence of material in the manuscript should be: title page, abstract, body of the manuscript, literature cited, tables with table headings, and figure legends and figures.

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Article:

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5. Each table, together with its heading, must be double spaced, numbered in arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print about 5 × 7 inches. Line drawings in India ink on white paper are acceptable. Photographs should have good contrast so that they can be reproduced satisfactorily. Figures should be numbered in arabic numerals.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly Extensive alterations on the galley proofs are expensive and such costs are to be borne by the author. Reprints are to be ordered when the galley proofs are returned to the Editor.

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TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

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Some Ecological Factors Affecting the Occurrence of Water Willow *Justicia americana* in Jessamine Creek, Kentucky

Henry H. Howell

Department of Biology, Asbury College, Wilmore, Kentucky 40390

Abstract

Efforts were made to determine what environmental conditions are conducive to the occurrence of water willow *Justicia* (= *Dianthera*) *americana* beds along the course of Jessamine Creek, which had been receiving about 650,000 gal/day (2,460 m^3/day) of secondary sewage effluent through 2 tributaries. There were no beds of water willow in the upper or lower extremities of the stream; beds were present only in a 12.7-km stretch downstream from the point where the sewage effluent first entered the main stream, and more than half the dense stands occurred within the uppermost 3.2 km of that stretch. Elevations in that stretch fell 70.1 m, yet the size of the beds did not seem affected by elevational changes. East or west flow seemed conducive to development of more extensive and dense beds. NPK did not appear limiting. Depth of gorge and length of available sunlight did seem to affect size and density of beds. Minor flooding seemed to increase riffle and patch size where beds already occurred; however, heavy flooding may have had an adverse effect on some stands. From 1971 to 1974, species composition and diversity of benthos and other animals more than doubled at one station where samples were taken both years.

Introduction

Jessamine Creek flows through one of the outstanding scenic gorges within the Blue Grass Physiographic Region of Kentucky (Dearinger 1968). Its course lies entirely within the Inner Blue Grass Subregion, centered around the city of Lexington in Fayette County. The stream originates 6.4 km south of the Fayette County line in Jessamine County, and empties into the Kentucky River without ever leaving Jessamine County. Jessamine Creek is a fifth-class stream (Kuehne 1962), and has cut its way through nearly 122 m of limestone to maintain its flow into the river. It is 30.9 km long, and for the last 9.7 km the stream flows through a narrow, heavily wooded valley with high cliffs on one or both sides.

Sewage disposal plants release effluents into 2 tributaries of the stream, Town Fork and Wilmore Branch (Fig. 1). In the last 5 years, a number of industries have moved into the drainage basin.

For the past 18 years, I have been interested in the water quality and biota of Jessamine Creek. I have seen darter (*Etheostoma*) and stonefly (Plecoptera) populations eliminated from parts of the stream, and the bottom become extremely slippery in riffles; yet, in the last 5 years, stream conditions have improved with reference to desirable fauna, and it appears that the changing flora may have been related to the improvement, since there has been a rapid extension of beds of water willow *Justicia* (= *Dianthera*) *americana* in

FIG. 1. Map of Jessamine Creek watershed showing the locations of the sampling stations (indicated by numbers), Town Fork, and other principal tributaries.

spring and summer along the course of the stream, and the presence of huge mats of filamentous algae during the winter. This paper discusses the results of data gathered largely from 1 July through 15 October 1974, in what was an effort to determine the ecological role of the extensive patches of water willow in Jessamine Creek, and to see if they could possibly be contributing to the improvement of water quality.

Water willow is one of the most commonly occurring angiosperms in the shallow waters of lakes, ponds, and streams in eastern United States and southern Canada (Fassett 1969). It is an emergent perennial herb, rather frequently found in dense and extensive stands. Numerous workers have studied the production, mineral nutrient absorption, and assimilation of aquatic flowering plants. Westlake (1963) and Boyd (1968, 1969) have summarized the rather extensive literature. Boyd (1969), in particular, found that stands of water willow in lentic and lotic situations in Alabama had high biomass productivities and mineral uptake during spring and early summer, with standing crops that averaged 3.75 times higher in the 2 lakes studied than in the 3 streams. Krumholz (1971), Krumholz and Neff (1972), White (1974), and Woodling (1970, unpublished master's thesis, University of Louisville, Louisville, Kentucky) all sensed the need for an intensive study of the large *Justicia* beds in the Salt River, Kentucky, to ascertain their contribution to the overall economy of the river.

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RECENT INVESTIGATIONS IN THE STUDY AREA

Since 1963, 18 undergraduate students at Asbury College have conducted brief independent investigations on Jessamine Creek, most work being done since 1970. One of the chief conclusions gathered from those reports is that total and fecal coliform counts increased below the Wilmore and Nicholasville sewage outfalls, with more rapid recovery in Wilmore Branch than in Town Fork, even though a higher count had been present below the Wilmore plant. In all reports, the total coliforms usually were higher than 5,000/100 ml.

In 2 unpublished reports by M. W. Jones, chemical analyses were run on water samples from selected stations; other than below the outfalls, orthophosphate ranged from 1.12 to 4.25 mg/l, and nitrate nitrogen from 4.25 to 7.08 mg/l. Other parameters determined were pH, sulfate, metaphosphate, conductivity, alkalinity, hardness, total dissolved solids, and dissolved oxygen. None of those factors were considered critical.

One of the most comprehensive studies was done in the fall of 1973 by Barcelo, who used stationary periphyton samplers to study the extent of colonization on glass slides placed in riffles for 4 exposure periods. She identified 46 genera in the samples, mostly diatoms. The dry weight per slide ranged from 0.5 to 13.3 mg, and the ash-free weights ranged from 0.1 to 9.6 mg. The ash-free weights averaged 57.5 percent of the dry weight, and at the station below the sewage outfalls, the weights were more than double those upstream from the outfalls.

In the summer of 1971, I had the assistance of 2 college seniors and 2 high school students under the National Youth Corps Program, and a paper entitled "Some of the effects of domestic sewage discharged into Hickman and Jessamine Creeks in Jessamine County, Kentucky" by Howell and Jones was presented to the Kentucky Academy of Science that fall, and again in March 1972 to the Midwest Benthological Society. The information used came from 8 riffle stations on Hickman Creek and 13 on Jessa-

TABLE 1.—RELATIVE ABUNDANCE, NUMBER OF STEMS PER SQUARE METER, PATCH SIZE (M^2), DIRECTION OF STREAM FLOW, AND TYPE OF VEGETATIONAL COVERAGE OF SURROUNDING SHORES, FOR WATER WILLOW BED AT EACH STATION IN JESSAMINE CREEK, KENTUCKY

Station Number	Relative Abundance	Number of Stems	Size of Patch	Direction of Flow	Shoreline Vegetation
1	Sparse to very thick	64–334	367	W & NW	Open field
2	Thick to very thick	360–476	1800	W	Open field
3	Medium thick	256[1]	232	S	Open field
4	Medium thick	252	203	W	Woods with little overhang
5	Sparse	–[2]	900	SW	Partial canopy
6	Sparse	60[1]	200	W	Partial canopy

[1] Floods made accurate count difficult.
[2] Too much flood damage to estimate.

mine Creek, and included data on water chemistry, coliforms, benthos, and fishes. Hickman Creek was judged more polluted than Jessamine Creek largely on the basis of the diversity of benthos and fishes. Hickman Creek was receiving about 1.3 million gal/day (4,920 m^3/day) of sewage effluent from the Lexington area, and Jessamine Creek was receiving about 650,000 gal/day (2,460 m^3/day) from Nicholasville and Wilmore.

In addition to the above-mentioned investigations, studies on the flora of the county have been made by members of the Department of Botany at the University of Kentucky. A master's thesis entitled "Vascular plants of Jessamine County, Kentucky" was written in 1941 by MacFarland, who listed 661 species including a number of rare species from the gorge. In 1974, MacGregor, a graduate student, presented a paper to the Academy on "The flora of Jessamine Gorge." He listed 344 species as occurring in the gorge, with 68 species being considered rare or near rare. The U. S. Army Corps of Engineers (1974) compiled a thorough study of the environmental resources of the Lexington Urban Area, and in the section dealing with flora, some special notes from Meijer (1974) were included, with comments on 15 rare species from the gorge.

METHODS

To determine the extent of water willow and other angiosperm beds in Jessamine Creek, the creek bed was cruised for its entire length, including Town Fork and Wilmore Branch. Whenever a patch of plants or an algal mat was found, its location was plotted on a 7.5-min topographic map. The size of each patch in square meters was determined from the length and average width. Relative density of the emergent stalks was recorded as very thick, thick, medium, or sparse. The direction of stream flow was recorded as N, S, E, W, NW or SE, NE or SW, along with the extent of overhead cover, whether there were open fields along banks, partial canopy, or full canopy. The presence or absence of noticeable current, the depth of water, and the type of substrate were also recorded.

After cruising the stream, 6 collecting stations were established (Fig. 1) at which detailed studies of water willow communities were made using 0.25-m^2 square metal frames to determine the average numbers of emergent stems per square meter and the average wet and dry weights of harvested stems. When collecting stems, an effort was made to collect benthos from around the roots. In addition, total dissolved solids using a Hach meter, total coliforms using the Millipore technique, and other chemical tests were determined as time permitted. Efforts were made to determine the size and composition of the fish, snake, and crayfish populations in and around the water willow beds.

RESULTS

By the end of July, 59 vegetational patches had been mapped. Extremely

TABLE 2.—NUMBERS AND SIZES OF PATCHES OF WATER WILLOW BETWEEN STATIONS IN JESSAMINE CREEK, TOGETHER WITH DISTANCES AND DIFFERENCES IN ELEVATION (MSL) BETWEEN STATIONS

Between Stations	No. Patches Between Stations	Distance Between Stations		Total Size of Patches (m^2)	Elevations (meters)	Fall in Stream	
		mi	km			m/km	Ft/mi
1–2	19	0.74	1.20	4,330	241.1–237.4	3.04	16.1
2–3	10	0.89	1.43	3,910	237.4–225.6	8.29	43.9
3–4	20	2.74	4.41	3,154	225.6–199.7	5.86	30.9
4–5	9	1.83	2.95	1,768	199.7–183.9	5.36	28.4
5–6	5	2.31	3.72	202	183.9–164.2	5.31	28.1
Totals	63	8.51	13.71	13,364	241.1–164.2		

heavy rains fell on the watershed the first 2 weeks in August, and by the end of the month there was an excess of 7.95 inches (20.19 cm) over the average rainfall of 3.50 inches (8.89 cm). September had one of the highest rainfalls on record, with an excess of 6.47 inches (16.43 cm). The lower 4.83 km of the creek was not visited until late August and September; flood damage had been extensive. Station 6 was selected on 22 September. The upper reaches of Jessamine Creek above Town Fork were not visited until October.

There were no beds of water willow in Town Fork, Wilmore Branch, or in Jessamine Creek above the mouth of Town Fork even though there were suitable riffle sites for such beds. There were occasional patches of lizard's tail *Saururus cernuus* upstream from the mouth of Town Fork, primarily along the margins of pools. Although there were no beds of water willow in Jessamine Creek upstream from the mouth of Town Fork, there were 63 beds downstream from that point. The extremely high floodwaters could have eliminated a few small beds before the lower reaches of the stream were surveyed.

The 6 stations for intensive study were selected because of the sizes of water willow beds and ease of access. At Station 1, 5 small beds were lumped together. The densest and largest beds were at or near Station 2, and although it cannot be stated conclusively because of the severe flooding, the density of the stands appeared to diminish downstream. The abundance, coverage, direction of flow, and adjoining riparian vegetation at each station are shown in Table 1. At Station 2, driftage was found almost 2 m above normal pool level, and at Station 4 it was nearly 3 m above normal pool level. The abundance and distribution of water willow beds in relation to declivity in Jessamine Creek are shown in Table 2, and Fig. 2 shows the profile of the stream and the relationship between station locations and declivity. Assuming that the portion of the stream that contains water willow beds is 13,720 m (8.52 miles) long and the average width is 10 m, the beds covered nearly 10 percent of the total streambed. Those beds covered 36 percent of the streambed between Stations 1 and 2, 27 percent between Stations 2 and 3, and only 7 percent between Stations 3 and 4. At the first 4 stations, the beds covered 60–95 percent of the streambed. The declivity of the streambed did not appear to influence the location of the beds.

At Station 1 and in several vegetational beds downstream, there was a mixture of water willow and lizard's tail. In 4 of 8 mixed beds, lizard's tail comprised 50 percent of the total coverage, in 3 other beds, lizard's tail was the only plant. Seven of the 11 beds of lizard's tail were along the stream bank.

An east or west flow may be conducive to enlarging the size of beds, since nearly 60 percent of all beds occurred in such locations (Table 3). Flow in either of those directions normally allows greater exposure to direct sunlight, especially in the gorge

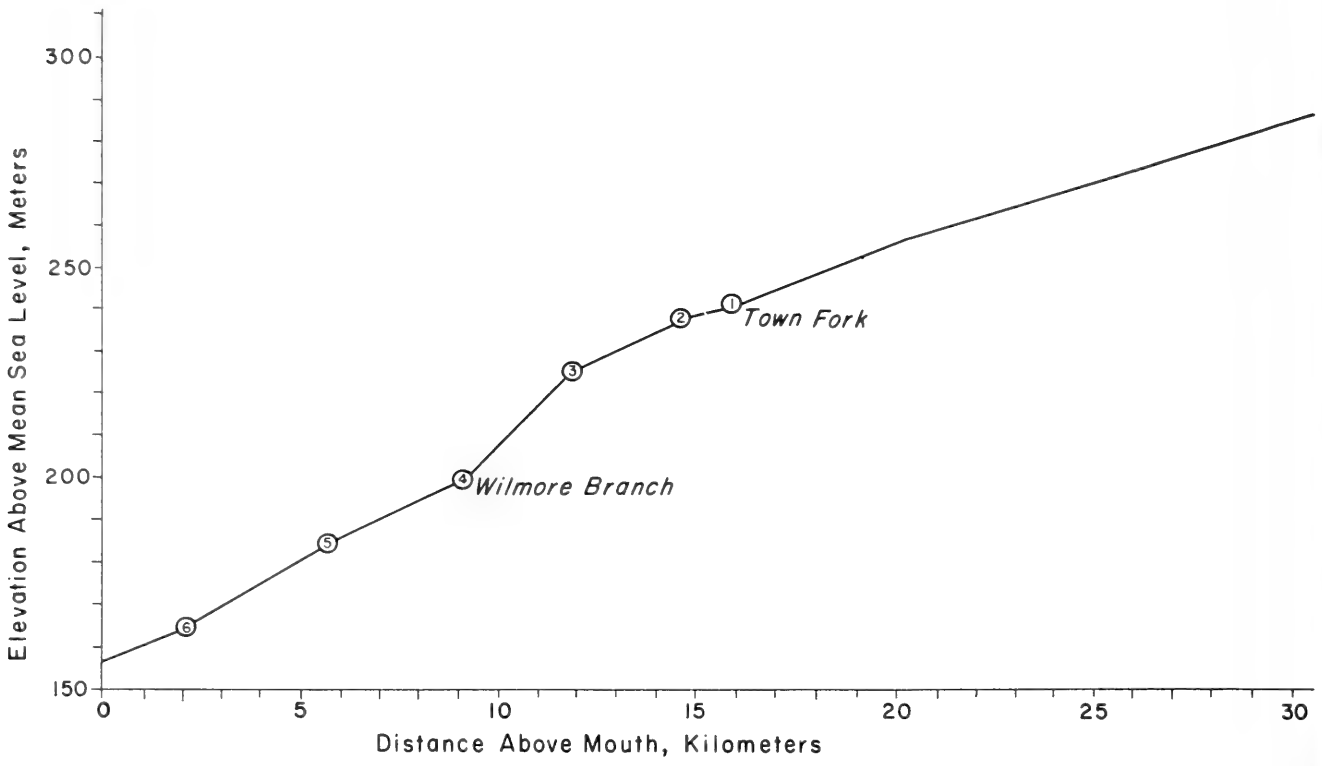

FIG. 2. Profile of Jessamine Creek showing the locations of the sampling stations and the points of confluence of Town Fork and Wilmore Branch.

portion. Only 23 percent of the water willow coverage was in areas of north–south flow.

In all larger beds, the water willow grew in riffle areas where the water was 2.5–7.5 cm deep. Of the 63 beds recorded, only 14 (22 %) were in shallow water along the banks of pools; the remaining 49 beds were in riffles and the coverage ranged from 2 to 1,800 m^2. The pattern of flow within each bed varied greatly. In a few beds it was almost impossible to see any flowing water without separating the dense willow shoots. Usually, in naturally occurring separations, larger volumes of water imparted a braided appearance to the stream. Horizontal runners attached the plants to the substrate, and almost any combination of boulders, rubble, gravel, sand, and silt was found associated with the beds.

The wet weight of the standing crop on 1 August in a medium dense bed at Station 4 was 2,917 g/m^2; the dry weight was 522 g/m^2. The latter figure falls within the range cited by Boyd (1969) in 3 Alabama streams (322–802 g/m^2 dry wt). Production from a dense stand in Jessamine Creek was not determined.

High waters had a very adverse effect on beds of water willow. All stems were bent

TABLE 3.—SUMMARIES OF WATER WILLOW COVERAGES IN SQUARE METERS ARRANGED ACCORDING TO DIRECTION OF STREAM FLOW. NUMBERS IN PARENTHESES INDICATE NUMBERS OF PATCHES

Stations	No. of Patches	E or W	N or S	NE or SW	NW or SE
1–2	19	3689 (8)	266 (3)		876 (8)
2–3	10	3213 (4)	97 (3)	5 (2)	600 (1)
3–4	20	180 (6)	2528 (8)	214 (5)	232 (1)
4–5	9	593 (5)	155 (2)	900 (1)	120 (1)
5–6	5	198 (3)	15 (1)		4 (1)
Totals	63	7873 (26)	3061 (17)	1119 (7)	1332 (12)

double with the exception of those at the upper ends of large beds where the stems brought about retardation of the current and rapid deposition of sediment that held the stems upright. Stems not broken, frequently became upright after flow receded to near normal for a few days. At the upper end of Station 2, 30.48 cm of sediment was deposited on top of the earlier exposed horizontal runners; at the lower end of the same bed, 10.16 cm of sediment had been deposited. The smaller volume of floodwater at Stations 1 and 2 allowed the beds there to survive the floods with less destruction.

Only 2 quadrat samples for benthos were taken, and only a small part of the known fauna was collected. In the associated riffles, 3 species of darters, a sculpin, 2 cyprinids, a sucker, and a smallmouth bass were taken by agitating the rubble. In the pools below, 2 species of crayfish, *Orconectes rusticus* and *O. juvenilis*, were collected. Prior to the flooding, large numbers of crayfish were seen in the pools below the water willow beds. Below Station 2, 96 adult crayfish were collected with a 10-foot seine. In the 0.25-m^2 benthos quadrat in the water willow bed at Station 2, 4 small crayfish ($16/m^2$) were taken. The water willow beds possibly served as nurseries for small crayfish. Those same riffles, with their many rocks and rubble, may also serve as hiding places during winter, since no crayfish were found in any of the pools after the first frost.

In the gorge area between Stations 4 and 5 where water funneled quite rapidly over a bedrock strip, large crayfish were arrayed in a military spacing 20–25 cm apart, all facing upstream and remaining motionless. Were they waiting drift organisms, filter feeding, or carrying on some unknown physiological activity?

In May 1974, 3 *Natrix sipedon sipedon* were taken in a seine from a riffle at Station 3. Subsequent effort to census the *Natrix* population at 4 collecting stations was unsuccessful. About a dozen were seen during the season, most of them in pools.

From the 49 water samples collected from Stations 1 through 4 from 17 July through 6 August 1974, conductivity ranged from 452 to 616 μmhos/cm, with the higher figure at Town Branch just above its confluence with Jessamine Creek and the lower one from Jessamine Creek just above its confluence with the Kentucky River. Total and fecal coliform counts from the same samples are listed in Table 4.

TABLE 4.—MEAN TOTAL COLIFORM COUNTS PER 100 ML FOR JESSAMINE CREEK ABOVE AND BELOW CONFLUENCE WITH TOWN BRANCH, AND BETWEEN COLLECTING STATIONS, 15 JULY–5 AUGUST 1974

Station	Count
Jessamine Creek (above confluence)	7,962
Town Branch (above confluence)	31,928
Between Stations	
1–2	9,575
2–3	10,575
3–4	7,811

DISCUSSION

The occurrence of water willow in Jessamine Creek may be related directly to the increased urbanization within the county, particularly in and around Nicholasville where increased amounts of water are being shunted directly into the stream, thereby increasing its silt carrying capacity. Similarly, the increased sewage load has resulted in a higher BOD in the discharge (pers. comm. from operator). It appears that the existing beds are being extended at both ends of the area they now occupy. In the lower gorge, the larger volume of water tended to retard the extension of the beds because of the narrower floodplains and the increasingly scouring action of the current, and, perhaps, less exposure to direct sunlight.

No reasons could be found for the absence of water willow plants in the waters of Town Fork which carried the sewage effluent from Nicholasville, or in the relatively clean waters of Jessamine Creek above the mouth of Town Fork since there were many locations that appeared suitable so far as substrate is concerned. Chemical analyses provided no clues, but it may be

that data on BOD, and more specifically on dissolved organic materials would provide insight.

In many pool areas, the bottom is bedrock and establishment of water willow beds or other plant communities would be difficult; still, some of the smaller beds were found in cracks and fissures within the shallow pools less than 30 cm deep. As with several other streams in the Inner Blue Grass, the entire flow goes underground during the late summer and early fall, so that only dry riffles and occasional pools remain. Jessamine Creek disappears 0.8 km below Station 3 and remains underground for about 1.4 km.

It is not known how effective water willow plants are in removing the nutrients from sewage having undergone secondary treatment. Law and Kerr (1969), over a 60-week period in Oklahoma, used fescue and rye grasses in hydroponic culture tanks with nutrient rates of 8,664, 4,560, and 4,833 lb NPK/acre (1,590, 837, and 887 kg/ha), respectively, with gravel beds to ascertain the effectiveness of mineral removal. They reported that grasses were minor contributors to nutrient removal from wastes when compared to the total quantity of nutrients that passed through the tanks. They also concluded that there was greater reduction of COD (50%), BOD (85%), and total nitrogen (55%) than the NPK by passage through the tanks. Interestingly, removal in the control tanks on organic materials and total nitrogen was about the same as in the experimental tanks with the grasses. Such information allows for the possibility that an indirect benefit of the increasing sizes of the water willow beds may be the furnishing of increased size to the gravel beds where flora and fauna would tend to reduce COD, BOD, and total nitrogen as well as total bacterial counts.

LITERATURE CITED

BOYD, C. E. 1968. Some aspects of aquatic plant ecology. Pp. 114–129. *In* Reservoir Fishery Resources Symposium, Amer. Fish. Soc., Washington, D. C.

———. 1969. Production, mineral nutrient absorption, and biochemical assimilation by *Justicia americana* and *Alternanthera philoxeroides*. Arch. Hydrobiol. 67:78–85.

DEARINGER, J. A. 1968. Esthetic and recreational potential of small naturalistic streams near urban areas. Univ. Ky. Water Res. Inst., Res. Rept. No. 13. 260 pp.

FASSETT, N. C. 1957. A manual of aquatic plants. Univ. Wis. Press, Madison, Wis. 405 pp.

KRUMHOLZ, L. A. 1971. A preliminary ecological study of areas to be impounded in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. No. 43. 35 pp.

———, AND S. E. NEFF. 1972. A preliminary ecological study of areas to be impounded in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. No. 48. 25 pp.

KUEHNE, R. A. 1962. A classification of streams illustrated by fish distribution in an eastern Kentucky creek. Ecology 43:608–614.

LAW, J. P., JR., AND R. S. KERR. 1969. Nutrient removal from enriched waste effluent by the hydroponic culture of cool season grasses. Water Res. Cent., Ada, Okla., Fed. Water Qual. Admin. Prog. No. 16080.

MEIJER, W. 1974. Some notes on flora and vegetation of the Lexington, Kentucky, urban area. P. 49. *In* Environmental resources inventory of the Lexington area. U. S. Army Corps of Engineers, Louisville District, Louisville, Ky.

U. S. ARMY CORPS OF ENGINEERS. 1974. Environmental resources inventory of the Lexington, Kentucky, urban area. U. S. Army Corps of Engineers, Louisville District, Louisville, Kentucky. Pp. 48–56.

WESTLAKE, D. F. 1963. Comparisons of plant productivity. Biol. Rev. 38:385–425.

WHITE, D. S. 1974. The distribution of stoneflies (Insecta: Plecoptera) of the Salt River, Kentucky. Trans. Ky. Acad. Sci. 35:17–23.

Why Mature Women Return to School: "Reasons" and "Motives"

Caroline F. Martin
Department of Sociology, University of Louisville, Louisville, Kentucky 40208

Abstract

This paper, written by a mature woman student as her senior thesis in Sociology, investigates the levels of rationalization employed by a sample of 51 mature women students at the University of Louisville in explaining their decision to return to school. The hypothesis, based on concepts of behavior and reasoning by past theorists, that these explanations would fall into two distinct levels, superficial 'reasons' and latent 'motives,' is supported by the research. The results suggest that disruptive conditions or events are important factors in the decision of older women to go back to school, and that education serves an important function in their lives.

Introduction

Individuals exhibit multiple levels of rationalization in explaining important decisions. This research investigates two of these levels through analysis of the experience of mature women who return to school.

In the past, many theorists have remarked upon the ways in which any human behavior is influenced. They noted that actions are affected by both reasoning and emotions; that behavior is not always consciously determined and recognized; and, that justifications of actions often cover motivations.

Pareto (1935:88), for instance, felt that *logical* actions are in large part the result of processes of reasoning, whereas actions which originate chiefly in psychic states, subconscious feelings, and the like are *nonlogical.* Timasheff (1967:163) summarized this in the following statement: "According to Pareto, an action is logical if its end is objectively attainable and if the means used are objectively united with the end in the framework of the best knowledge available; all other actions are nonlogical." Pareto (1935:104) also said that the human being has a weakness for adding logical development to nonlogical behavior and, according to Timasheff (1967:163), some men "justify their actions by formulating nonlogical theories which their advocates consider to be highly logical." Every social phenomenon, therefore, may be considered under two aspects: as it is in reality, and as it presents itself to the mind of the human being (Pareto 1935:76). Thus, it cannot always be counted on that what people say about their actions is entirely factual or enlightening. Timasheff (1967:164) agreed that ". . . to explain actions by accepting at face value what men say about their behavior is, of course, a procedure void of scientific validity—a principle long recognized by students of human life."

Merton (1957:24) also believed that it need not be assumed that the reasons advanced by people for their behavior are one and the same as the observed consequences of these patterns of behavior. Merton (1957:51) used the terms *manifest* and *latent*; manifest being the intended and recognized form of behavior, and latent being neither intended nor recognized. Timasheff (1967:225) phrased it this way: "Manifest functions refer to the objective consequences of a specific social cultural unit which contribute to its adoption or adjustment and were so intended by the participants; latent functions refer to unintended and unrecognized consequences."

Another theorist, Weber (*in* Timasheff 1967:178), acknowledged that considerable social conduct is marked by the person's inarticulate half-consciousness or even unawareness of its meaning. This usually occurs, he felt, when the conduct is a social habit or when it involves personal feelings. "Lack of awareness of meaning is quite common, in fact, when behavior is *traditional*, that is, determined by social custom, or when it is *affective*, that is determined by emotion."

In studying decision making, it has been

found that 'stereotype' questions often bring stereotyped or superficial answers. According to Goode and Hatt (1952:167–168), a question that begins 'Why did you—?' in an attempt to find out why the respondent made a certain choice, usually elicits that which comes to the respondent's mind most quickly, and is likely to be a justification of the decision, rather than a true disclosure of the circumstances that led to it. Cliches come quickly to mind as they are a large part of social communication and they are no exception in the interview. "In the interview, as in daily conversation, the respondent's verbal habits are likely to be in cliche form" (Goode and Hatt 1952:163). It is necessary to probe more deeply if the cliches which are used to cover motivations are to be avoided (Goode and Hatt 1952: 200).

In view of the concepts regarding behavior and reasoning already discussed, it is to be anticipated that the accounts given by individuals of important events and decisions in their lives will be found to have two more or less distinct aspects: a superficial one containing 'reasons' or 'explanations' easily given in response to questionnaire or interview items, and a latent one involving 'motives' (distinctively different from the superficial material) linked to important needs, tensions, and issues in their personal lives. To evaluate this supposition, the present study focuses upon an important life decision of the mature woman—that of going back to school.

Little research has been done in the area of the mature female student. Feldman's (1972:993) study concerning graduate students and marital status found that the most committed and active students were the divorced women. "It is almost as if they were making up for lost time by becoming fully immersed in the student role." Clements (1974:23) reported that older women were more effective academically and had more emotional equanimity and competence than the younger students.

It was expected that the reasons for returning to school given by the mature students on first contact would be the superficial-manifest or rationalized reasons, and the latent reasons or actual motives would have to be probed for.

That these motives would involve important needs, tensions, and issues in the personal lives of these mature women students is based on the observation that people more or less consciously attempt to attain some basic routine, as a normal state of affairs, in their daily living. This routine lends equilibrium to their lives and, once it is achieved, they seldom voluntarily disrupt it. To deliberately change the routine is to invite disequilibrium and its accompanying costs in anxiety, confusion, and readjustment. Of course, disequilibrium can also occur involuntarily, due to unforeseen or uncontrollable events which yield new issues, needs, and tensions. A new routine then becomes necessary in order to regain the desired equilibrium and sense of well-being.

It is the presumption of this study that the mature woman student's decision to return to school after a gap of years represents a characteristic reaction to some sort of disruption in her life. In other words, some disruptive condition or event upset her routine thereby threatening her equilibrium. The decision to go back to school is a form of adaptive response to these changed circumstances.

Not all change, of course, is disruptive. For the woman whose children grow up and leave home, there is change but it is natural, gradual, expected, and usually prepared for through the years. Unexpected and unplanned for change, however, can violently disrupt routine and cause considerable disequilibrium. A woman does not, presumably, anticipate marital problems, for example, when she promises to be a wife 'until death do us part.' Yet, when these problems threaten her wifely routine, her equilibrium is adversely affected. Perhaps some difficulties with children in their teenage years might be expected, but these become disruptive problems when they involve delinquent behavior. Illness may be natural and death inevitable but when loved ones are stricken, the life and routine of every

woman is disrupted. Being uprooted from her home is also an upsetting experience for a woman. She leaves behind her established routine, her familiar neighborhood, and old friends and acquaintances. This can be gradual and eased by frequent visits and telephone calls if the move was not too distant. A major shift in residence, however, results in an abrupt change in secure surroundings, associations, and daily routine. In her search for a new routine and restored equilibrium, the mature woman may be forced to seek a new role. For the women in this study, that new role is the role of a student.

The hypothesis to be tested in this study, therefore, is that mature women students, when asked why they returned to college (a major life decision), will typically offer reasons that could be classified as superficial. However, when interviewed in depth, their answers will contain a large proportion of reasons classified as latent, involving disruptive conditions or events in their personal lives.

METHODS

The research was carried out in Louisville, Kentucky, at the Belknap Campus of the University of Louisville during the fall semester 1974. At the beginning of the semester, a list of names and addresses of 143 women over 30 years of age who had been registered in the University during the spring of 1974 was obtained from the office of the Dean of Students. However, because of the time limit of one semester, it was decided to contact only those women on the list who were enrolled in the College of Arts and Sciences, a total of 85 persons.

In order to test the hypothesis, it was decided that the first contact would be by telephone, followed by a personal interview with a random subsample of the telephone respondents. The responses received in both telephone and personal interviews were expected to fall into two categories, *superficial* reasons and *latent* reasons. Those reasons classified as superficial included: intellectual stimulation, a desire to upgrade or change jobs, to increase skills or effectiveness, looking for independent alternatives, and such phrases as 'I had time on my hands,' 'I just wanted to,' 'I always planned to continue,' 'I didn't like to work,' 'I didn't want to stay at home,' and 'It gave me an interest in common with my husband.' Those circumstances classified as latent included: marital problems, problems with teenagers, family illness, death in the family, and a major shift in residence.

Telephone numbers of the 85 students in the sample were obtained, but of those, 14 were unavailable and were dropped from the roster, leaving a total of 71 names with telephone numbers. Of that 71, 1 had married and moved away, 9 numbers were either wrong or had been reassigned, 7 were no longer in service, and 3 were never answered during the time allotted for data collection, even though calls were made at varying hours of the day throughout the week. A final total of 51 mature women students were successfully contacted by telephone. When calling, I explained how I had secured the respondent's name and identified myself as a fellow mature student working on my senior thesis in sociology. Each respondent was asked why she had decided to return to school, and all responses were noted.

From those 51 students, a subsample was drawn at random and consisted of 21 numbers (41 % of the total). Of that 21, 3 refused to be interviewed personally, pleading lack of time in their busy schedules. Two more pleaded lack of time at the present, but offered to accommodate me at a later date, but the time limit on data collection precluded accepting their offers. Sixteen of the subsample agreed to be interviewed personally and appointments were made with each one. Of that 16, only 1 failed to keep her appointment. The rest, 29 percent of the total sample, were interviewed as scheduled. Questions in the interview were designed to remind the respondent of the conditions in her life at the time she decided to return to school, such as her marital status, the ages of her children, and her place of residence at the time of her decision, not at the time of the interview. She

TABLE 1.—TOTAL NUMBER AND PERCENTAGES OF SUPERFICIAL AND LATENT REASONS BY TELEPHONE AND IN-DEPTH INTERVIEWS, 51 MATURE WOMEN STUDENTS, UNIVERSITY OF LOUISVILLE, FALL, 1974

	Phone Interview		In-depth Interview	
Reasons	N	%	N	%
Superficial	46	90	7	47
Latent	5	10	8	53
Totals	51	100	15	100

was then asked to tell me how it happened that she decided to return to school. All responses were recorded, and both the telephone and personal interviews were tabulated and summarized according to the previously established criteria.

RESULTS

The contact by telephone elicited the largest number (46) and the largest percentage (90 %) of superficial reasons (Table 1). Not only were the majority of responses superficial, but many respondents (15 of 51, 29 % of the total) offered more than 1 superficial reason for returning to school, giving a total of 67 superficial responses (Table 2). Only 1 respondent, after giving an initial superficial reason, followed it with one classified as latent. Of the 4 who responded initially in the latent category, only 1 gave more than 1 reason, and that, too, was classified as latent. The majority of students interviewed personally, however, gave latent reasons for their decision to return to school (Table 1). Of the 15 students interviewed personally, 7 (47 %) gave reasons classified as superficial and 8 (53 %) gave reasons classified as latent. All of the 7 responding superficially gave more than 1 superficial reason. Of the 8 who gave latent responses, 2 gave initial responses that were superficial but their secondary responses, as the interview progressed, fell into the latent category. One of these asked for further reassurance of confidentiality before emitting her latent response. Her request came abruptly, near the middle of the interview. She had been asked about the timing of her return to school; 'Why then, not sooner or later?' She began to answer, citing the extra time on her hands that her child's entrance into school allowed, when suddenly she stopped. With lowered voice she questioned whether her answers would, indeed, be kept in confidence. When this was confirmed, she admitted to having a personal problem and talked for some time about its effect on her life. Later she commented on feeling better about the personal interview than she had about the telephone interview because, she said, she had been more truthful. The other case of a secondary latent response was less dramatic, evolving quite naturally through the respondent's reflecting back over time. Of the remaining 6 latent responders, 3 gave

TABLE 2.—SUPERFICIAL AND LATENT REASONS RECEIVED IN TELEPHONE AND PERSONAL INTERVIEWS, 51 MATURE WOMEN STUDENTS, UNIVERSITY OF LOUISVILLE, FALL, 1974

	Responses				
	Telephone Interview			Personal Interview	
Reasons	1st	2nd	3rd	1st	2nd
Superficial					
Intellectual stimulation	1	1			
Always planned to continue	12	2	1	4	
Increase skills or effectiveness	10	4			
Desire to upgrade or change job	8	1	3		
Search for independent alternative	2	2			2
Time on my hands	5	1		3	1
Just wanted to	5	1			
Didn't want to stay at home	3		1	2	1
Didn't like to work	1				1
Need common interest with husband		3			2
Totals	47	15	5	9	7
Latent					
Marital problems	2			1	1
Problems with teenagers					1
Illness in the family	2			1	
Death in the family		1		1	1
Major shift in residence		1		3	2
Totals	4	2		6	5

only 1 response and 3 gave 2 responses. Thus, a total of 16 superficial reasons and 11 latent reasons were given by the respondents during the personal interviews.

It must be acknowledged here that I, a student, was an inexperienced interviewer. It is felt in retrospect that the first few interviews (which elicited superficial responses) suffered from that lack of experience and that had they been conducted either at a later time or by a more experienced interviewer the results might have been even more decisive. The loss from the sample of 6 women, 5 who lacked the time for the interview and 1 who failed to keep her appointment, might also have biased these results. Their loss leaves in question whether the remaining 15 were actually representative of the total population. The results are also limited in terms of the small size of the sample available. Allowing for these possible limitations, a chi-square test of significance was performed on the data in Table 1. The test yielded a chi-square value of 11.6578 which is significant at beyond the .001 level of confidence.

CONCLUSION

The above results indicate that disruptive conditions or events in her personal life are often important factors in the mature woman's decision to return to school. Not only are these factors important, but the research also suggests that the woman herself is either not aware of their influence or suppresses them as reasons, feeling, perhaps, that they are either illogical or socially unacceptable. The number of cliches elicited on first contact illustrates the woman's unawareness or rationalization through stereotyped answers or justifications. The concentration of superficiality in the phrase, 'I always planned to continue,' implies an unawareness of the decision making process itself. If it had always been planned, no decision or any explanation would have been necessary. Increasing skills and effectiveness, the category which had the next most responses, is certainly a socially acceptable reason for returning to school for anyone, especially in this culture where self improvement is so highly regarded. On the other hand, those who gave latent reasons when called were those who appeared to recognize and find logical the relationship between their return to school and the disruptive conditions or events in their personal lives. They seem to have had no need for repression or self-justification, but their number was few.

The fact that the personal interview brought out latent reasons in a majority of subjects is not surprising. Different methodologies can result in different responses. The relaxed atmosphere of face-to-face contact with a fellow mature student who has 'been there' might be expected to be more conducive to openness, requiring less self-justification and defensiveness than the contact by an unknown voice on the telephone. Several respondents commented on their lack of honesty when they were first contacted, saying that they didn't even remember what they had said on the telephone or that they wondered after they hung up why they had said what they did.

Not all of those interviewed personally gave latent reasons, however. This may have been due to unawareness of their behavior as a consequence of disruptive conditions or events or, if aware, an inability or unwillingness to admit it to others. There is a possibility that in some cases none of these disruptive conditions did exist. There is also the possibility that some women had many reasons for returning to school and some were expressed in the telephone interview and others in the personal interview.

In the majority of the personal interview cases, however, there were disruptive conditions or events. This study supports the conclusion that their occurrence influenced the return to school of these older women. It suggests that intellectual activity in the form of continuing education may act as a balm for emotional distress. A mind busy acquiring new knowledge cannot dwell on painful experience or memories. There may be security in the student role with its regularity of routine. Scheduled classes, assignments, and deadlines direct the mind and body outward, away from the emotions,

while healing time passes. It might also mean that emotional stress is a major element in motivating people to change their roles. In the case of the mature woman, education would appear to serve a transitional or adaptive function in that change. Being a student for a time not only increases her skills and enhances her self-confidence, but also makes the role change a more gradual process. She may move, for example, from the security of home to the secure but competitive campus to the competitive world of employment. Thus, she adapts by stages and over a period of time.

These older women who return to school have so far been virtually ignored in current research literature. Many aspects of the situation of the mature women students appear worthy of investigation. It might prove fruitful, for example, to study their goals. What are they and are they achieved? Also of interest would be a comparison of the students cited in this study with others enrolled in other universities and colleges. Do older women who choose a community or church affiliated college have the same reasons and motives as those enrolled in a state university? Another interesting topic of investigation would be the socioeconomic background of the women who go back to school. Does one class predominate? How important is income? A study of the academic achievement of mature women students might also prove interesting. How do they compare academically with their younger counterparts and/or with their past school performance? It is hoped that in the future more will be learned about these mature women students.

LITERATURE CITED

CLEMENTS, K. 1974. Emotional characteristics of mature women students in education. Res. Educ. 9(7):23.

FELDMAN, S. D. 1972. Impediment or stimulant? Marital status and graduate education. Amer. J. Sociol. 78:982–994.

GOODE, W. J., AND P. K. HATT. 1952. Methods in social research. McGraw-Hill Book Co., New York, N. Y. 376 pp.

MERTON, R. K. 1957. Social theory and social structure. Free Press, Glencoe, Ill. 645 pp.

PARETO, V. 1935. The mind and society. Harcourt, Brace, and Co., New York, N. Y. 4 Vol., 2033 pp.

TIMASHEFF, N. S. 1967. Sociological theory. Random House, New York, N. Y. 335 pp.

Auchenorrhynchus[1] Hosts of Mermithid Nematodes in Kentucky[2]

Christina Sperka and Paul H. Freytag
Department of Entomology, University of Kentucky, Lexington, Kentucky 40506

Abstract

About 60,000 specimens of auchenorrhynchus Homoptera collected from various habitats in Kentucky during 1972–1974 were examined for parasites. More than 200 specimens of unidentified larval mermithid nematodes were dissected out from auchenorrhynchs representing at least 37 species in 7 families. Overall rate of parasitism was about 0.3 percent. Mermithids did not appear host specific, and collection site and date appeared more important in determining rate of parasitism than species of auchenorrhynchs present. Mermithid parasites did not produce measurable effects in genitalia or other external structures; however, abdominal distention, color changes, and absence of internal organs were observed. Dryinid (Hymenoptera) larvae and halictophagid (Strepsiptera) adults and larvae were sometimes found coexisting with mermithid parasites.

Introduction

Insects are the commonly reported hosts of the nematode family Mermithidae (Nickle 1972). Although there are more than 23,000 species of Homoptera belonging to the suborder Auchenorrhyncha (cicadas, leafhoppers, spittlebugs, and planthoppers), few members of this group are recorded as hosts for mermithids. Zwaluwenberg (1928) reported *Aenolamia varia saccharina* Distant (Cercopidae) from Trinidad as parasitized by *Mermis* sp. LaRivers (1949) discussed *Agamermis unka* Kaburaki and Inamura from Japan and its araeopid (delphacid) hosts, *Nilaparvata oryzae* Matsumura and *Liburnia furcifera* Horvath. Weaver and King (1954) stated that the grasshopper mermithid, *Agamermis decaudata* Cobb, Steiner, and Christie, was found in the meadow spittlebug, *Philaenus spumarius* (L.) in Ohio. In this paper, we report the results of a study conducted in Kentucky from 1972 to 1974 which yielded data concerning the incidence of mermithid nematodes in auchenorrhynchus hosts.

Acknowledgments

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Materials and Methods

About 60,000 specimens of adult and nymphal auchenorrhynchus Homoptera (excluding Cicadidae) were collected, mainly from grassy pastures and old field habitats, from 81 Kentucky counties during 1972–1974 (Mar–Dec). Samples usually were obtained by sweep net collection, although hand, shrub beating, and blacklight collecting methods were also used. All specimens were preserved in 80 percent ethanol. Samples were sorted to species or higher groups, and all specimens in each group were dissected and examined for parasites.

[1] Homoptera: Auchenorrhyncha.

[2] The investigation reported in this paper (No. 75-7-77) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

TABLE 1.—AUCHENORRHYNCHUS HOSTS OF MERMITHID NEMATODES IN KENTUCKY

Host	Counties in Which Hosts with Mermithids Were Collected	Range of Collection Dates
Cercopidae		
Clastoptera sp.	Wayne	18 Jul
Philaenus spumarius (L.)	Grayson	13 Jun
Cicadellidae		
Acertagallia sanguinolenta (Provancher)	Fayette	13 May
Agallia constricta Van Duzee	Barren, Breathitt, Fayette, Green, Jefferson, Mercer, Monroe, Oldham, Taylor	13 May–15 Aug
Agallia quadripunctata (Provancher)	Anderson	13 Jun
Alebra albostriella (Fallen)	Breathitt	6 Jul
Amblysellus curtisi (Fitch)	Fayette	7 Jul
Balclutha abdominalis (Van Duzee)	Breathitt	29 Jun
Chlorotettix unicolor (Fitch)	Grant	15 Aug
Coelidia olitoria (Say)	Fayette	23 Jul
Cuerna costalis (F.)	Fayette	23 Jul
Draeculacephala antica (Walker)	Boyle, Fayette, Grant, Green, Hart, Henry, Marion, Meade, Mercer, Metcalfe, Oldham, Shelby, Spencer, Taylor, Warren	19 May–29 Oct
D. mollipes (Say)	Fayette	1–9 Aug
Draeculacephala spp. (undetermined females and nymphs)	Breathitt, Fayette, Henry, Jefferson, Meade, Oldham, Shelby, Spencer, Trimble, Warren, Wayne, Woodford	10 May–14 Sep
Empoasca sp.	Boyle, Fayette, Mercer, Oldham, Rockcastle	17 Jun–15 Aug
Forcipata loca DeLong & Caldwell	Breathitt, Fayette, Henry	22 Jun–9 Oct
Graminella nigrifrons (Forbes)	Fayette, Hancock	3 Jun–10 Oct
Graphocephala versuta (Say)	Boyle, Fayette, Mercer	9–12 Aug
Idiocerus pallidus Fitch	Fayette	24 Jun
Laevicephalus orientalis DeLong & Davidson	Larue	17 May
Latalus sayi (Fitch)	Fayette, Henry	13 May–15 Aug
Macrosteles fascifrons Dorst	Breathitt, Fayette	19 May–14 Jun
Paraphlepsius irroratus (Say)	Fayette, Spencer	4 Jun–15 Aug
P. tenessa (DeLong)	Boyle	12 Aug
Polyamia weedi (Say)	Fayette	22 Jun–9 Oct
Psammotettix striatus (L.)	Boone, Breathitt, Fayette, Warren	10 May–29 Oct
Stirellus bicolor (Van Duzee)	Fayette	6 Jun
Tylozygus bifidus (Say)	Pendleton, Shelby	27 Jun–15 Aug
Cixiidae		
Oliarus ecologus Caldwell	Boone, Shelby	27 Jun–15 Aug
O. sablensis Caldwell	Boone	27 Jun
Delphacidae		
Delphacodes lutulenta (Van Duzee)	Boone	27 Jun
Delphacodes spp.	Boone, Fayette	27 Jun–29 Oct
Delphacidae (undetermined species)	Fayette	22 Jun–24 Aug
Dictyopharidae		
Scolops sulcipes Say	Wayne	22 Jul
Issidae		
Thionia simplex (Germar)	Oldham	15 Aug
Membracidae		
Campylenchia latipes (Say)	Scott	19 Jul
Stictocephala bubalus (F.)	Gallatin	19 Jul
S. lutea (Walker)	Jefferson, Spencer	15 Aug

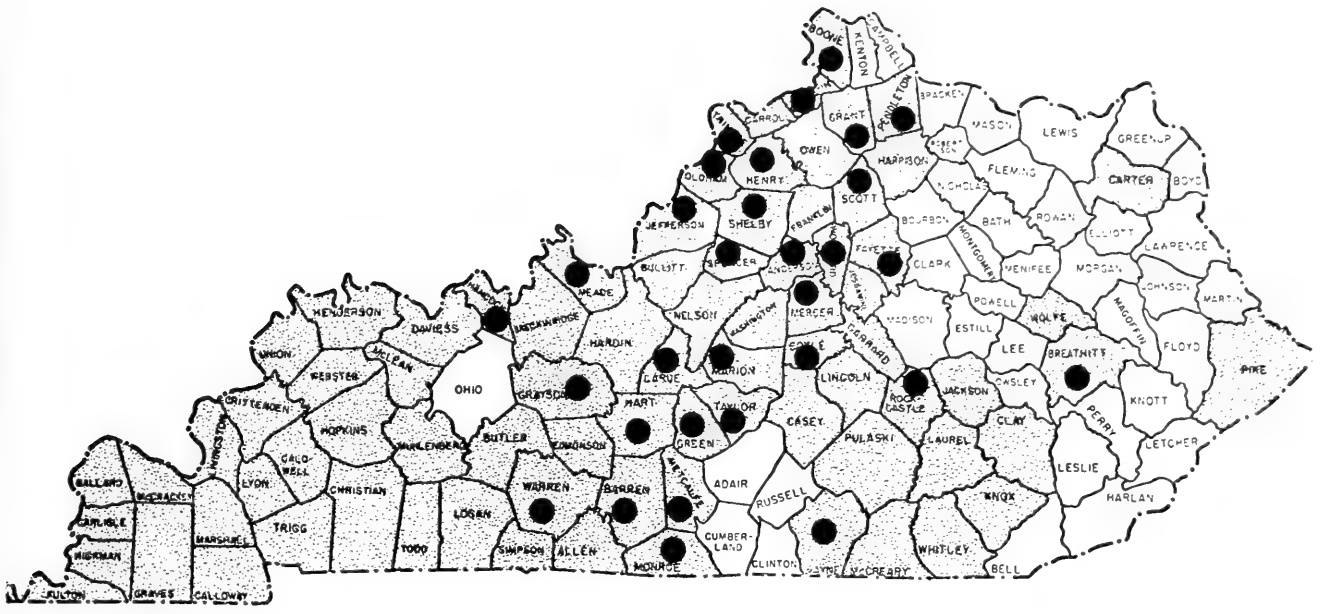

FIG. 1. Distribution of auchenorrhynchus specimens parasitized by mermithid nematodes in Kentucky. Stippled areas represent counties sampled for auchenorrhynchs. Filled circles indicate counties from which mermithids were collected.

During 1973–1974 about 8,000 specimens of living auchenorrhynchs were collected for parasite rearing studies. Mermithids which emerged from their hosts were incubated at 27 ± 3 C on damp sand. Adult mermithids, necessary for identification, were not obtained.

RESULTS AND DISCUSSION

Hosts

More than 200 specimens of larval mermithid nematodes were dissected out from auchenorrhynchus specimens representing at least 37 species in the Cercopidae, Cicadellidae, Cixiidae, Delphacidae, Dictyopharidae, Issidae, and Membracidae (Table 1).

Distribution

Mermithid parasites were found in collections from 31 counties, primarily in the central third of the state (Fig. 1). Although the western third of the state was well sampled and collections usually yielded auche-

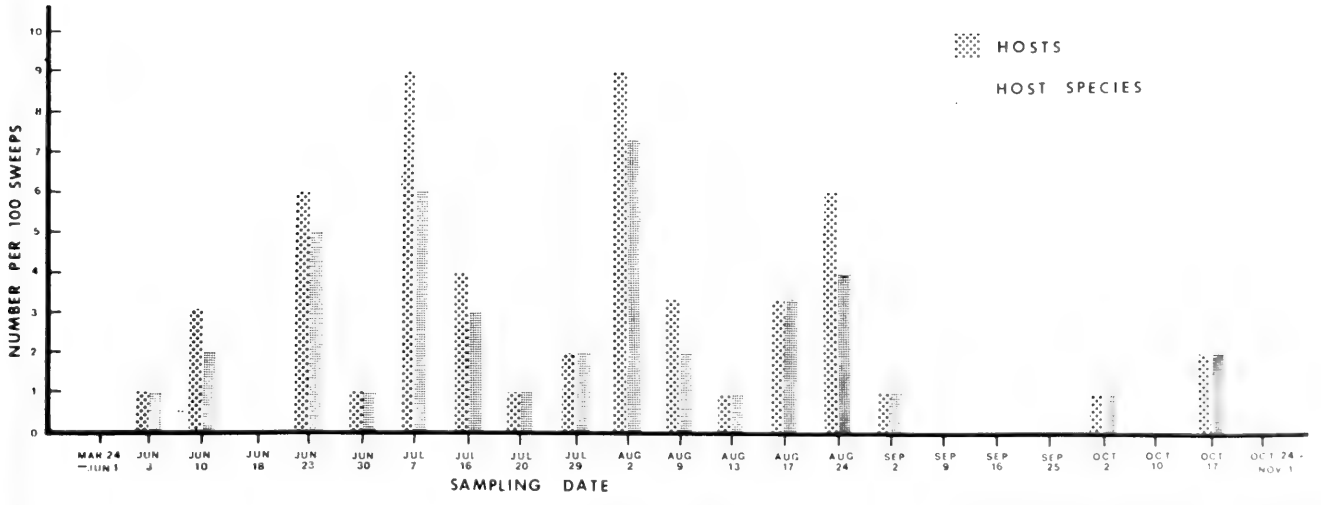

FIG. 2. Trend of abundance of mermithid parasitized hosts and number of host species involved. Fayette County, 1973.

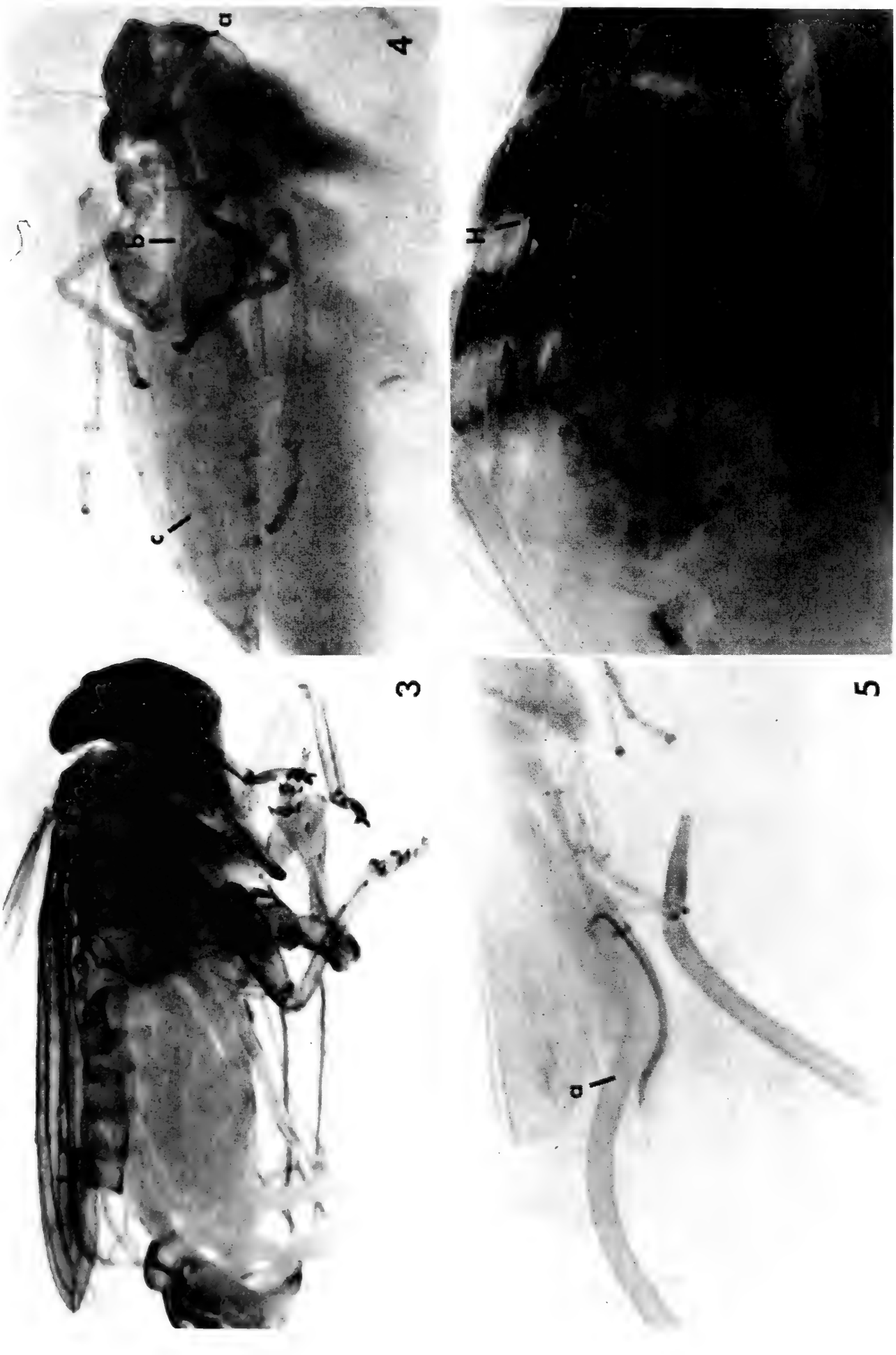

FIG. 3. *Thionia simplex* with mermithid in abdominal cavity. FIG. 4. Nymph of *Draeculacephala* sp. with mermithid extending into head (a), thoracic cavity (b), and abdominal cavity (c). FIG. 5. Nematode emerging via the anus (a) of *Empoasca* sp. FIG. 6. Mermithid sharing abdominal cavity of *Draeculacephala antica* with gravid female halictophagid: (e) eyespots of halictophagid embryos, (H) cephalothorax of female halictophagid.

norrhynchus specimens similar to those in the central portion of the state, few mermithids were found in that area. A visual inspection of these data indicate that this distributional pattern is not correlated with maps of mean annual rainfall, generalized geology, or major soil areas.

Mermithids were found in their hosts from 10 May until 29 October. These early and late collection dates indicate that mermithids can overwinter in their hosts. Results from weekly sampling at a Fayette County site during 1973 indicate that mermithids were most common from late June through August (Fig. 2).

Rate of Parasitism and Host Specificity

Of the nearly 60,000 specimens examined, only about 200 were parasitized by mermithids. This represents an overall rate of parasitism of approximately 0.3 percent. Although more than a fourth of the mermithids collected were parasitic in the leafhopper genus *Draeculacephala*, the rate of parasitism by mermithids in this group was not higher than the overall rate.

Little is known of the host specificity of most mermithid species; however, it is apparent that those which attack the leafhoppers and their allies are not species specific. Collection site and date appeared more important in determining rate of parasitism than species of auchenorrhynchs present. At most localities sampled, if more than 1 parasitized host was found in a sample, more than 1 host species was involved usually in a ratio proportional to the number of auchenorrhynch species collected. This is exemplified by data from Fayette County (Fig. 2).

Mermithids in Their Hosts

The mature larval mermithid fills the abdominal cavity of its host (Fig. 3). Frequently, coils of the nematode also extend into the thoracic and head areas, completely filling the body of the host (Fig. 4).

Most hosts examined could be placed in 2 size groups: those about 3 mm long and those 7–8 mm long. The longest nema found in the small-host group was 38 mm in length from a female cicadellid, *Psammotettix striatus*, which was 3.4 mm long. The average mermithid length for the small-host group was about 26 mm (S.E. 7.8 mm, $n = 20$). The longest nema found in the larger hosts was 84 mm long in an 8.5 mm membracid, *Stictocephala bubalus*. The average mermithid length in this host size class was about 43 mm (S.E. 12.2 mm, $n = 51$).

Usually, only 1 mermithid was found in each host; however, up to 4 were observed. Nemas from superparasitized hosts frequently were shorter than the average length of a nema from the same host species when that species was singly parasitized.

Parasitism by mermithids seldom produced measurable effects in the genitalia or other external structures of their hosts; however, abdominal distention and color changes were observed in a few specimens. Internal organs usually were absent or greatly reduced, and "parasitic castration" was evident.

Rearing studies showed that death of the host occurred either shortly before or after the emergence of the mermithid from the body of the host. The nematode emerged from the host usually via a hole in the intersegmental membrane of the abdominal sclerites or through the anus (Fig. 5) or genital openings.

Association of Mermithids with Other Parasites

Although the mermithid usually renders its auchenorrhynchus host sterile, it does coexist with certain insects which are also parasitic in the Auchenorrhyncha. Both larvae of the Dryinidae (Hymenoptera) and adults and larvae of the Halictophagidae (Strepsiptera) were found in hosts parasitized by mermithids. Several specimens were found bearing well-developed mermithids and female halictophagids which had reproduced as evidenced by their burden of triungulin larvae (Fig. 6). Although the mermithids parasitize many of the same host species as do the larvae of the Pipuncu-

lidae and Tachinidae (Diptera), no mermithids were found in association with these larvae.

LITERATURE CITED

LARIVERS, I. 1949. Entomic nematode literature from 1926 to 1946 exclusive of medical and veterinary titles. Wasmann Collector 7(5):177–206.

NICKLE, W. R. 1972. A contribution to our knowledge of the Mermithidae (Nematoda). J. Nematol. 4(2):113–146.

WEAVER, C. R., AND D. R. KING. 1954. Meadow Spittlebug. Ohio Agric. Expt. Sta. Res. Bull. 741. 99 pp.

ZWALUWENBURG, R. H. VAN. 1928. The interrelationships of insects and roundworms. Bull. Expt. Sta. Hawaii Sugar Planters' Ass., Entomol. Ser. 20:1–68.

The Fishes of West Kentucky. III. The Fishes of Bayou de Chien

David H. Webb and Morgan E. Sisk
Hunter Hancock Biological Station, Department of Biological Sciences,
Murray State University, Murray, Kentucky 42071

Abstract

An annotated list of fishes representing 16 families and 53 species taken from Bayou de Chien is presented. Numbers of 3 rare and/or endangered species from Kentucky (*Etheostoma histrio*, *E. asprigene*, and *Percina uranidea*) may be large enough to ensure their continued existence under present conditions, but 2 other species (*Lepomis symmetricus* and *Hybognathus hayi*) are recommended for inclusion on the state's rare and endangered list of fishes. An observation indicates that Bayou de Chien may serve as a nursery area for *Polyodon spathula*.

Introduction

Published accounts of the fishes in the Jackson Purchase region of western Kentucky are sparse. The first published collections from this area are those of Woolman (1892), which he collected from Mayfield and Obion creeks and Bayou de Chien during 3 days. Those collections were limited to 1 or 2 stations along each stream and do not approximate total species composition of any of the above drainage systems. A summary of all ichthyological work done in the Tennessee and Kentucky regions was produced by Evermann (1918) and included Woolman's (1892) work. Recent studies by Clay (1962), Sisk (1969), and Smith and Sisk (1969) have included notes on the ecology and distribution of fishes in the Purchase area. The works of Forbes and Richardson (1920), Baker (1937, 1939a, 1939b), Baker and Parker (1938), Pflieger (1971), Resh et al. (1973) relate to fishes from regions bordering the Jackson Purchase. These studies are applicable because western Tennessee, southeastern Missouri, southern Illinois, and western Kentucky are geographically similar, and historically shared a common piscine fauna.

This study of Bayou de Chien was undertaken as part of a regional survey to establish the extant piscine fauna of western Kentucky. Bayou de Chien is in the southwestern portion of the Jackson Purchase and drains 216 square miles (559 km^2) (Schwendeman 1958) in Graves, Hickman, and Fulton counties. The basin is about 48 km long and 16 km wide with an east–west orientation. The source of the stream is in southwestern Graves County from whence it flows some 47 km to its confluence with the Mississippi River. All but the terminal 8–10 km of Bayou de Chien have been subjected to channelization in the past. The present mouth of the stream is about 1.6 km north of Hickman, Kentucky.

The general supposition, supported by Loughridge (1888), is that Obion Creek and Bayou de Chien once formed a single stream that flowed near the base of the bluffs at Hickman, and then continued southwesterly into Tennessee. A change in the channel of the Mississippi from west to east of Island No. 6 has resulted in the obliteration of a bottom which was present near the Hickman bluffs in 1842 (Loughridge 1888). Thus Obion Creek and Bayou de Chien, now with separate outlets to the Mississippi River, once coursed through the Reelfoot Lake area and were tributaries of the Obion River system of western Tennessee. An old stream channel, known as Running Slough, may today be seen along State Highway 94 for several kilometers southwest of Hickman. Running Slough can be traced to Reelfoot Lake where its channel is called the old Bayou de Chien. Sisk (1973) suggested that the old channel serves as a route of reinvasion for fishes from Reelfoot Lake, following periods of drought, into streams of southwestern Fulton County, Kentucky.

TABLE 1.—RESULTS OF WATER ANALYSIS OF BAYOU DE CHIEN, 1972–1973

	Range		
	Min	Max	Mean
Oxygen (ppm)	5	14	8.9
pH	6.0	8.9	7.1
Turbidity (JTU)[1]	5	800	80.3
Chlorides (ppm)	5	35	7.8
Temperature (°C)	5	32	18.4

[1] Jackson turbidity units.

Basic water quality parameters were measured quarterly during this survey and are summarized in Table 1. Tests for nitrogen and phosphorus were omitted due to inadequate field methods for analysis.

MATERIALS AND METHODS

Gill nets, hoop nets, fish traps, an electric shocker, creel census, and seines were used in sampling the fishes of Bayou de Chien. Specimens were killed and fixed in formalin and preserved in alcohol. Collections are in the Murray State University Vertebrate Museum.

Twenty major collecting sites, sampled on a quarterly basis, were selected along the course of Bayou de Chien and its tributaries. The selection of sampling stations was based primarily on accessibility and were generally near highways or roads. Twelve additional collections were made at various localities during the course of the study in an effort to sample all aquatic habitats. The results of this study are based on a total of 103 collections.

Listed below are the sampling stations followed by the dates on which collections were made.

1. Bayou de Chien near its confluence with the Mississippi River, 1.6 km NE of Hickman, Fulton Co. 19:VIII:1972, 28:V:1973, 8:XII:1973.
2. Little Mud Creek, 3.2 km E of Hickman, Fulton Co., at Kentucky Highway 94. 21:X:1972, 19:VI:1973, 19:IX:1973.
3. Mud Creek, 6.4 km E of Hickman, Fulton Co., at Kentucky Highway 94. 6:X:1972, 19:VI:1973, 14:VII:1973, 7:VIII:1973.
4. Samson Creek, 4.8 km NW of Cayce, Fulton Co., at Kentucky Highway 1129. 9:IX:1972, 11:XI:1972, 9:III:1973, 16:VI:1973.
5. Tributary of Mud Creek, 3.2 km SW of Cayce, Fulton Co., at Kentucky Highway 1128. 2:IX:1972, 28:V:1973, 2:X:1973.
6. Little Bayou de Chien, 4.8 km N of Cayce, Fulton Co., at Kentucky Highway 239. 2:IX:1972, 6:X:1972, 9:III:1973, 21:V:1973, 28:V:1973, 1:IX:1973.
7. Little Bayou de Chien, 3.2 km NE of Cayce, Fulton Co., at Kentucky Highway 1907. 22:VII:1972, 16:VIII:1972, 24:II:1973, 19:VI:1973, 13:XI:1973.
8. Little Bayou de Chien, 7.2 km SE of Cayce, Fulton Co., at Kentucky Highway 1125. 7:VIII:1972, 2:IX:1972, 24:II:1973, 19:VI:1973, 13:XI:1973.
9. Bayou de Chien, 6.4 km N of Cayce, Fulton Co., at Kentucky Highway 239. 9:IX:1972, 30:IX:1972, 9:III:1973.
10. Bayou de Chien, 0.8 km N of Moscow, Hickman Co. 6:VIII:1972, 13:X:1972, 21:X:1972, 24:II:1973, 16:VI:1973, 7:VIII:1973.
11. Bayou de Chien, 4.8 km SE of Clinton, Hickman Co., at U.S. Highway 51. 16:VIII:1972, 23:IX:1972, 24:II:1973, 16:VI:1973.
12. Cane Creek, 6.4 km SE of Clinton, Hickman Co., at Kentucky Highway 1529. 13:X:1972, 17:II:1973, 13:IV:1973, 19:IX:1973.
13. Cane Creek, 8.0 km SE of Clinton, Hickman Co., at U.S. Highway 51. 16:VI:1972, 23:IX:1972, 9:III:1973, 21:V:1973.
14. Bayou de Chien, 4.8 km SW of Fulgham, Hickman Co. 30:IX:1972, 2:II:1973, 30:III:1973, 7:VIII:1973.
15. Bayou de Chien, 4.8 km S of Fulgham, Hickman Co., at Kentucky Highway 307. 16:VI:1972, 29:VIII:1972, 23:IX:1972, 21:X:1972, 3:II:1973, 13:IV:1973, 18:VII:1973.
16. Sand Creek, 4.0 km S of Fulgham, Hick-

man Co., at Kentucky Highway 307. 16:VI:1972, 23:IX:1972, 21:V:1973.
17. Bayou de Chien, 4.8 km N of Water Valley, Hickman and Graves cos., at Kentucky Highway 1283. 7:VI:1972, 22:VII:1972, 30:IX:1972, 2:II:1973, 30:III:1973.
18. Bayou de Chien, 1.6 km NW of Water Valley, Graves Co., at U.S. Highway 45. 7:VI:1972, 22:VII:1972, 23:IX:1972, 17:II:1973, 13:IV:1973.
19. Bayou de Chien, 3.2 km NE of Water Valley, Graves Co., near Bayou de Chien Church. 30:V:1972, 6:X:1972, 17:II:1973, 27:V:1973.
20. South Fork Bayou de Chien, 2.4 km E of Water Valley, Graves Co. 30:V:1972, 2:IX:1972, 2:X:1972, 17:II:1973, 27:V:1973.
21. Bayou de Chien, 4.8 km W of Moscow, Fulton Co., near the Adam's mounds. 27:VIII:1973.
22. Bayou de Chien, 3.2 km W of Moscow, Fulton Co. 1:IX:1973.
23. Drainage ditch, 6.1 km N of Cayce, Hickman Co., at Kentucky Highway 239. 2:IX:1972.
24. Bayou de Chien, 6.4 km SW of Fulgham, Hickman Co. 4:XI:1972.
25. Slough, 4.8 km W of Moscow and S of the Adams mounds, Fulton Co. 27:VIII:1973, 1:IX:1973.
26. Jackson Creek, 2.0 km NE of Water Valley, Graves Co., at U.S. Highway 45. 7:VII:1972.
27. Tributary to Bayou de Chien, 0.5 km S of Water Valley near Illinois Central RR, Graves Co., at Kentucky Highway 94. 29:VIII:1972.
28. Tributary to South Fork of Bayou de Chien, 5.6 km S of Water Valley, Graves Co., at Kentucky Highway 94. 30:V:1972.
29. Rush Creek, 4.8 km NW of Cayce, Fulton Co., at Kentucky Highway 1129. 9:IX:1972.
30. Slough N of Moscow, Hickman Co. 18:VI:1973, 14:VII:1973.

RESULTS

This survey resulted in the capture of specimens of the following fishes, representing 16 families and 53 species. The scientific name is followed by the common name, collecting sites, and notes on the distribution and abundance of each species. The nomenclature and arrangement of taxa are those of Moore (1968) and Bailey et al. (1970).

LIST OF SPECIES

POLYODONTIDAE

1. *Polyodon spathula* (Walbaum). Paddlefish. Stations 1 and 21. Rare and confined to the extreme low-gradient portions of the drainage.

LEPISOSTEIDAE

2. *Lepisosteus oculatus* (Winchell). Spotted gar. Station 22. Apparently rare in the system as only a single specimen was collected, that being from a quiet inlet just off the main stream.
3. *L. platostomus* Rafinesque. Shortnose gar. Stations 1, 3, 6, 10, 11, 21, 25, and 30. Fairly common in the low-gradient portions of the drainage and were particularly abundant following the extensive flooding caused by backwaters of the Mississippi River in the spring of 1973.

AMIIDAE

4. *Amia calva* Linnaeus. Bowfin. Stations 2, 6, 13, and 30. Rare in streams with flowing water and mainly confined to the quiet waters of sloughs, borrow ditches, and intermittent pools of the lowlands.

CLUPEIDAE

5. *Dorosoma cepedianum* (Lesueur). Gizzard shad. Stations 1, 3, 6, 10, 11, 21, and 22. Common in the low-gradient portions of the drainage and frequently captured in sloughs, borrow ditches, and main stream pools.

ESOCIDAE

6. *Esox americanus vermiculatus* Lesueur. Grass pickerel. Stations 4, 7, 8, 10, 11, 13, 14, 17, 18, 20, and 25. Distributed

throughout the drainage and frequently seen lying in debris and vegetation bordering streams and flooded areas.

CYPRINIDAE

7. *Carassius auratus* (Linnaeus). Goldfish. Station 3. Only one specimen was taken and probably represents an introduction rather than an established population.
8. *Cyprinus carpio* Linnaeus. Carp. Stations 1, 3, 6, 7, 9–12, 25, and 29. Common in the low-gradient portions of the drainage and a frequent inhabitant of sloughs and pools of streams.
9. *Hybognathus hayi* Jordan. Cypress minnow. Stations 3, 4, 6, and 22. Rare, and collected only in low-gradient streams from pools and areas with little or no current.
10. *H. nuchalis* Agassiz. Silvery minnow. Stations 6, 7, 9, and 10. Uncommon, and a lowland species which was most often taken from side pools of the main stream.
11. *Notemigonus crysoleucas* (Mitchill). Golden shiner. Stations 2, 3, 5–12, 14, 15, 18, 25, and 30. Widely distributed.
12. *Notropis emiliae* (Hay). Pugnose minnow. Stations 4, 9, 11, 12, 14, and 15. Most captures from the lowland areas of the system. Although widely distributed, this species was never collected in large numbers.
13. *N. fumeus* Evermann. Ribbon shiner. Stations 6–12, 14–18, and 21–24. The most numerous shiner in the drainage. Prefers quiet water and pools in both high- and low-gradient portions of streams.
14. *N. lutrensis* (Baird and Girard). Red shiner. Stations 9 and 17. Confined to riffles where it is occasionally taken in fairly large numbers. Dr. Glen Clemmer (pers. comm.) suspected that some of the specimens collected during this study are *N. lutrensis* × *N. venustus* hybrids.
15. *N. spilopterus* (Cope). Spotfin shiner. Station 17. Rare. Only a few specimens were collected from a riffle with sand bottom.
16. *N. venustus* (Girard). Blacktail shiner. Stations 14 and 15. An inhabitant of riffles in the high-gradient portions of the stream and apparently rare.
17. *Phenacobius mirabilis* (Girard). Suckermouth minnow. Stations 5, 14–18, and 24. Common in the high-gradient portions of the drainage and usually taken in or below swift riffles with sand and gravel bottoms. Frequently taken with *Percina uranidea.*
18. *Pimephales promelas* Rafinesque. Fathead minnow. Stations 2 and 5. An inhabitant of intermittent pools and quiet waters of the lowlands where it is rare.
19. *Semotilus atromaculatus* (Mitchill). Creek chub. Stations 5, 13–20, and 25–27. Confined mainly to the high-gradient portions of the system and often the most abundant species of extreme headwater streams with continuous flow.

CATOSTOMIDAE

20. *Erimyzon oblongus* (Mitchill). Creek chubsucker. Stations 4, 15, and 18–20. A common occupant of pools in headwaters and high-gradient portions of the stream.
21. *Ictiobus bubalus* (Rafinesque). Smallmouth buffalo. Stations 1, 3, 4, 6, 10, and 25. Fairly common in the low-gradient portions of the drainage where most captures were from sloughs, borrow ditches, and pools of the main stream.
22. *I. cyprinellus* (Valenciennes). Bigmouth buffalo. Stations 6 and 25. Uncommon and taken only from sloughs and borrow pits in the lowlands.
23. *Minytrema melanops* (Rafinesque). Spotted sucker. Stations 14 and 17. Several large individuals sighted at Station 17 in the early spring of 1974, but apparently rare in the drainage at other times of the year.

ICTALURIDAE

24. *Ictalurus furcatus* (Lesueur). Blue catfish. Although no specimens were collected, this species is reported by com-

mercial fishermen of the area to ascend Bayou de Chien and Little Bayou de Chien in early spring.

25. *I. melas* (Rafinesque). Black bullhead. Stations 1–6, 8, 9, 13, 20, 25, 29, and 30. Common in the lowlands and seems to prefer the same general habitat as *I. natalis*.
26. *I. natalis* (Lesueur). Yellow bullhead. Stations 1–4, 6–18, 20, 23, and 25. Common throughout the system and frequently taken from pools and areas with little or no current.
27. *I. punctatus* (Rafinesque). Channel catfish. Stations 1, 9–11, and 22. A lowland species that local fishermen reported from several localities other than those listed above.
28. *Noturus gyrinus* (Mitchill). Tadpole madtom. Stations 4, 6, 9, and 10. Restricted to the lowlands where it is usually found under overhanging banks or in clumps of leaves and other debris.
29. *N. nocturnus* Jordan and Gilbert. Freckled madtom. Stations 9, 10, 14, and 22. Uncommon and collected from the same general habitat as *N. gyrinus*.
30. *Pylodictis olivaris* (Rafinesque). Flathead catfish. Taken near our Station 21. Sight record of the head of a specimen taken by local fisherman and reportedly weighed 45 pounds (20.4 kg).

CYPRINODONTIDAE

31. *Fundulus olivaceus* (Storer). Blackspotted topminnow. Stations 1–4, 6–20, and 23–29. One of the most common species, distributed throughout the system and preferring quiet pools.

POECILIIDAE

32. *Gambusia affinis* (Baird and Girard). Mosquitofish. Stations 1–29. Probably the most abundant species in the system. An inhabitant of intermittent pools, borrow pits, backwaters, and pools of the main stream.

APHREDODERIDAE

33. *Aphredoderus sayanus* (Gilliams). Pirate perch. Stations 2–4, 6–13, 18, 21, 22, 28, and 29. Fairly common in the lowland portion of the drainage and most frequently taken in vegetation and debris along the margins of streams, flooded areas, and sloughs.

PERCICHTHYIDAE

34. *Morone chrysops* (Rafinesque). White bass. Station 1. Known to ascend the main stream in early spring during flood periods.

CENTRARCHIDAE

35. *Centrarchus macropterus* (Lacépède). Flier. Stations 2, 4, 6, 11, 25, and 30. Fairly common in the lowlands in sloughs and pools.
36. *Elassoma zonatum* Jordan. Banded pigmy sunfish. Stations 4, 6, 8, 9, 11, 14, and 17. Not common although several specimens were taken in all parts of the drainage. This species was collected in large numbers at Station 11 only during the spring of 1973.
37. *Lepomis cyanellus* Rafinesque. Green sunfish. Stations 2–5, 7–11, 13, 15–20, and 25–27. Common throughout the system with the largest populations occurring in the high-gradient portion of the drainage.
38. *L. gulosus* (Cuvier). Warmouth. Stations 2–4, 6–17, 21, 22, and 24. Fairly common throughout the drainage system except in extreme headwater streams.
39. *L. humilis* (Girard). Orangespotted sunfish. Stations 3, 5, 6, and 10. Confined to the lowlands where it is fairly common in pools, sloughs, and ditches.
40. *L. macrochirus* Rafinesque. Bluegill. Stations 1–20, 23, 25, and 29. Abundant throughout the drainage system and most frequently taken from pools.
41. *L. symmetricus* Forbes. Bantam sunfish. Stations 6 and 11. Rare, collected only from borrow ditches and a flooded area in the low gradient portion of the stream.
42. *Micropterus salmoides* (Lacépède). Largemouth bass. Stations 1, 3, 4, 6, 10, 11, 14, 15, 17, and 30. Fairly common throughout the drainage although not in large numbers. Most specimens taken

with seines were small, but creel census data showed that individuals of 2–3 pounds (4.4–6.6 kg) are not uncommon in the lowland parts of the system.

43. *Pomoxis annularis* Rafinesque. White crappie. Stations 1, 3, 4, 6, 9, 11, 22, and 30. Common and collected mainly from pools of streams, borrow pits, sloughs, and flooded areas.
44. *P. nigromaculatus* Lesueur. Black crappie. Stations 3, 4, and 11. Not as common as *P. annularis* with most captures from masses of vegetation in flooded areas and ditches.

PERCIDAE

45. *Etheostoma asprigene* (Forbes). Mud darter. Stations 1, 9, 10, 21, and 22. Confined to the lowland portion of the main stream where most captures were from riffles and matted roots along the bank.
46. *E. chlorosomum* (Hay). Bluntnose darter. Stations 1, 3, 4, 6, 10–15, 17, 18, and 22–24. Common and usually found in sloughs, pools, and other areas lacking noticeable current. This species represents the *E. nigrum* reported by Woolman (1892), (pers. comm. R. M. Bailey 1974).
47. *E. gracile* (Girard). Slough darter. Stations 1–20, 23, 24, 26, and 29. The most common percid encountered in this survey. Occurring throughout the drainage system with the greatest concentration in the lowlands.
48. *E. histrio* Jordan and Gilbert. Harlequin darter. Stations 9, 10, 14, and 15. Relatively rare, although common in riffles at Station 10 during certain times of the year.
49. *E. squamiceps* Jordan. Spottail darter. Stations 9, 10, and 14–19. Fairly common in the high gradient portions of the stream with occasional specimens being taken from lowland streams with moderate flow.
50. *Percina sciera* (Swain). Dusky darter. Stations 9 and 11. Confined to the lowlands where it is rare and most often found in fibrous roots bordering riffles.
51. *Percina uranidea* (Jordan and Gilbert). Stargazing darter. Stations 9, 10, 12, 14, 15, 17, and 24. Fairly common in riffles of the high-gradient portion of the stream where it was usually collected over a sand and gravel substrate. Often collected with *Phenacobius mirabilis*.
52. *Stizostedion canadense* (Smith). Sauger. Station 1. One specimen was taken in a gill net and probably was a migrant from the Mississippi River.

SCIAENIDAE

53. *Aplodinotus grunniens* Rafinesque. Freshwater drum. Stations 1 and 9. Confined to the lowlands where it is probably more abundant than is indicated by this study.

DISCUSSION

The collections of Woolman (1892) from Bayou de Chien included several species of fishes intolerant of high turbidity. These include *Lepomis megalotis*, *Labidesthes sicculus*, *Micropterus dolomieui*, *Notropis whipplei*, *Percina caprodes*, and *P. maculata*. Extensive clearing of native forests of the area and the conversion of the land for agrarian use may account for the increased silt load in the stream system. Absence of these fishes from the present study may be the result of an increase in stream turbidities since the 1890's. Another reason these species are absent in our collections may not be misidentification by Woolman as much as an increase in taxonomic and systematic expertise since Woolman's time.

The absence of *Centrarchus macropterus*, *Lepomis humilis*, *Gambusia affinis*, *Ictalurus natalis*, *I. melas*, and *Etheostoma gracile* from Woolman's collections is also surprising since all are common lowland species inhabiting the Coastal Plain. *Cyprinus carpio*, an inhabitant of all major drainages of the United States and recently reported from Canada, is not among the species reported by Woolman (1892). The appearance of *C. carpio* in the Jackson Purchase region may postdate 1890, since Woolman did not report it from any part of Kentucky west of the Tenessee River.

Miller (1972) placed 3 species of fishes taken during this study on the rare and endangered species list for Kentucky. *Etheostoma histrio* and *E. asprigene* are regarded as rare and endangered while *Percina uranidea* is listed as rare. Populations of *E. asprigene* and *P. uranidea* in Bayou de Chien probably are large enough to ensure their continued existence barring major stream changes. *E. histrio* is much rarer and exhibits a more limited distribution and narrower habitat requirements than the other 2 percids. Any type of dredging or channelization of Bayou de Chien would seriously threaten existing populations of *E. histrio*.

Two other fishes collected during this study, *Lepomis symmetricus* and *Hybognathus hayi*, appear in danger of extirpation from the northern limits of their ranges. Both are inhabitants of the Coastal Plain (Moore 1968), and are thus restricted in the Commonwealth to the extreme western half of the Jackson Purchase. *L. symmetricus* is on the rare and endangered species list of Missouri and Illinois (Miller 1972) and in Missouri is restricted to a single locality in the southeastern portion of the state (Pflieger 1971). *H. hayi* has not been collected in Missouri since the 1940's (Pflieger 1971) and is possibly extinct in the state. Past studies by Smith and Sisk (1969), Sisk (1973), and the present study indicate that *H. hayi* and *L. symmetricus* are rare in the Jackson Purchase region of Kentucky and that protective measures need to be instituted to ensure their existence in the state.

Little was known about the spawning habits of *Polyodon spathula* until Purkett (1961) observed the species spawning over gravel bars in Missouri's Osage River. The spawning habits of *P. spathula* in Kentucky are unknown (Clay 1962). In August 1973, a 23-cm specimen was taken from Bayou de Chien at Station 21. According to the studies of Purkett (1961), and Houser and Bross (1959) this juvenile was probably spawned in May 1973. If this specimen was not spawned over gravel and sand bars that are 13–16 km upstream from the point of collection, then it appears that Bayou de Chien at least serves as a nursery for the young paddlefish.

It should be noted that such species as *Umbra limi*, *Notropis maculatus*, *Fundulus chrysotus*, *F. notti*, *Menidia audens*, *Etheostoma fusiforme*, and *E. proeliare* were absent in collections from Bayou de Chien. All these fishes were reported by Sisk (1973) from nearby Running Slough and lakes of the lowlands southwest of Hickman, Kentucky, and may be suspected of occurring in the Bayou de Chien drainage system.

LITERATURE CITED

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. No. 6:1–150.

BAKER, C. L. 1937. The commercial, game and rough fishes of Reelfoot Lake, Tennessee. Rept. Reelfoot Lake Biological Station, J. Tenn. Acad. Sci., 12(1):9–59.

————. 1939a. Additional fishes of Reelfoot Lake. J. Tenn. Acad. Sci. 14(1):6–40.

————. 1939b. Key to Reelfoot Lake fishes. J. Tenn. Acad. Sci. 14(1):41–45.

————, AND M. V. PARKER. 1938. The fishes of Reelfoot Lake. J. Tenn. Acad. Sci. 13(2): 160–163.

CLAY, W. M. 1962. A field manual of Kentucky fishes. Ky. Dept. Fish. Wildl. Resources. The Dunne Press, Louisville, Ky. 147 pp.

EVERMANN, B. W. 1918. The fishes of Kentucky and Tennessee: A distributional catalogue of the known species. Bull. U. S. Bur. Fish. 35: 293–368.

FORBES, S. A., AND R. E. RICHARDSON. 1920. The fishes of Illinois. 2nd ed., Ill. Nat. Hist. Surv., Dept. Regist. Educ., Springfield, Ill. 359 pp.

HOUSER, A., AND M. G. BROSS. 1959. Observations on growth and reproduction of paddlefish. Trans. Amer. Fish. Soc. 88(1):50–52.

LOUGHRIDGE, R. H. 1888. Report on the geologic and economic features of the Jackson Purchase Region embracing the counties of Ballard, Calloway, Fulton, Graves, Hickman, McCracken, and Marshall. Geol. Surv. Ky., Frankfort, Ky. 357 pp.

MILLER, R. R. 1972. Threatened freshwater fishes of the United States. Trans. Amer. Fish. Soc. 101(2):239–252.

MOORE, G. A. 1968. Fishes. 144 pp. *In* Vertebrates of the United States, 2nd ed., McGraw-Hill Book Co., New York, N.Y.

PFLIEGER, W. L. 1971. A distributional study of Missouri fishes. Univ. Kans. Publ., Mus. Nat. Hist. 20(3):225–570.

RESH, V. H., C. R. BAKER, AND W. M. CLAY. 1973. A preliminary list of fishes of the Land Between the Lakes, Cumberland and Tennessee river drainages. Trans. Ky. Acad. Sci. 33(3–4):73–80.

SCHWENDEMAN, J. 1958. Geography of Kentucky. Harlow Publ. Co., Oklahoma City, Okla. 213 pp.

SISK, M. E. 1969. The fishes of west Kentucky. I. Fishes of the Clark's River. Trans. Ky. Acad. Sci. 30(3–4):54–59.

———. 1973. Six additions to the known piscine fauna of Kentucky. Trans. Ky. Acad. Sci. 34(3–4):49–50.

SMITH, P. L., AND M. E. SISK. 1969. The fishes of west Kentucky. II. The fishes of Obion Creek. Trans. Ky. Acad. Sci. 30(3–4):60–68.

WOOLMAN, A. J. 1892. Report of an examination of the rivers of Kentucky, with lists of the fishes obtained. Bull. U.S. Fish. Comm. 10: 249–288.

Distribution and Life History Notes on the Taillight Shiner *Notropis maculatus* in Kentucky

Brooks M. Burr and Lawrence M. Page
Illinois Natural History Survey, Urbana, Illinois 61801

Abstract

Notropis maculatus is present in Ohio River oxbows in Ballard and McCracken counties, Kentucky. Populations in these oxbows are the northernmost known of the species, and life history characteristics are compared to those of a central Florida population.

Citing 3 localities, Sisk (1973) recorded the presence of *Notropis maculatus* in extreme southwestern Kentucky, and expressed the opinion that these localities represented the northernmost limit in range of the species. In fact, however, *N. maculatus* also occurs, sometimes commonly, in the series of oxbow lakes lining the southern edge of the Ohio River in Ballard and McCracken counties in western Kentucky (Fig. 1). These oxbows are deep, have cypress swamp margins, and at least some of them are contiguous with the Ohio River during periods of flood.

In the Ohio River oxbows, *N. maculatus* was found mainly in marginal vegetation and in accumulations of sticks and debris in shallow water. Specimens collected have been deposited in the Illinois Natural History Survey (the number of specimens is given in parentheses): KENTUCKY, Ballard Co.: Mitchell Lake, 2 km NW Oscar, 29 August 1970 (6); 27 September 1973 (1); Butler Lake, 5 km NW Oscar, 14 August 1969 (3); Fish Lake, 5 km W Barlow, 10 September 1968 (2); Prairie Lake, 5 km W Gum Corners, 30 August 1970 (20); slough, 5 km W Gum Corners, 31 August 1970 (43). McCracken Co.: Crawford Lake, 3 km N Ragland, 14 August 1969 (4); Metropolis Lake, 5 km N Grahamville, 9 September 1967 (5); 10 September 1969 (10); 28 May 1972 (83); 26 April 1975 (5). Other fishes collected with *N. maculatus* in those lakes were *Polyodon spathula, Lepisosteus osseus, Amia calva, Dorosoma cepedianum, Esox niger, Hybognathus hayi, H. nuchalis, Notemigonus crysoleucas, Notropis emiliae, N. spilopterus, Noturus gyrinus, Fundulus notatus, F. olivaceus, Gambusia affinis, Labidesthes sicculus, Aphredoderus sayanus, Lepomis cyanellus, L. gulosus, L. humilis, L. macrochirus, L. megalotis, L. microlophus, L. punctatus, Micropterus salmoides, Pomoxis annularis, P. nigromaculatus, Etheostoma asprigene, E. chlorosomum, E. gracile, E. proeliare,* and *Percina caprodes.*

The new localities (Fig. 1) apparently represent the northernmost limit in range of *N. maculatus.* A large amount of unsuccessful effort has been expended in searching for the species on the Illinois side of the Ohio River. Pflieger (1971, 1974) discussed the probable extirpation of the species from Missouri where it has not been found in more than 30 years. The general range of *N. maculatus* is described by Cowell and Barnett (1974).

The hiatus between the Ohio River oxbow records and the Mississippi River backwater pond records in southwestern Kentucky (Fig. 1) may be due to a lack of adequate collecting; however, an examination of topographic maps for the region of the hiatus reveals an apparent lack of suitable habitat for *N. maculatus* (i.e., few oxbows, sloughs, or backwater ponds) in this region and the species may actually be absent.

Collections of *N. maculatus* in the Ohio River oxbows have been made in April (5 specimens), May (83), August (77), and September (21), and some comparisons with life history characteristics of the species in central Florida as described by Cowell and Barnett (1974) can be made.

In Metropolis Lake, McCracken County, on 28 May 1972, a school of *N. maculatus*

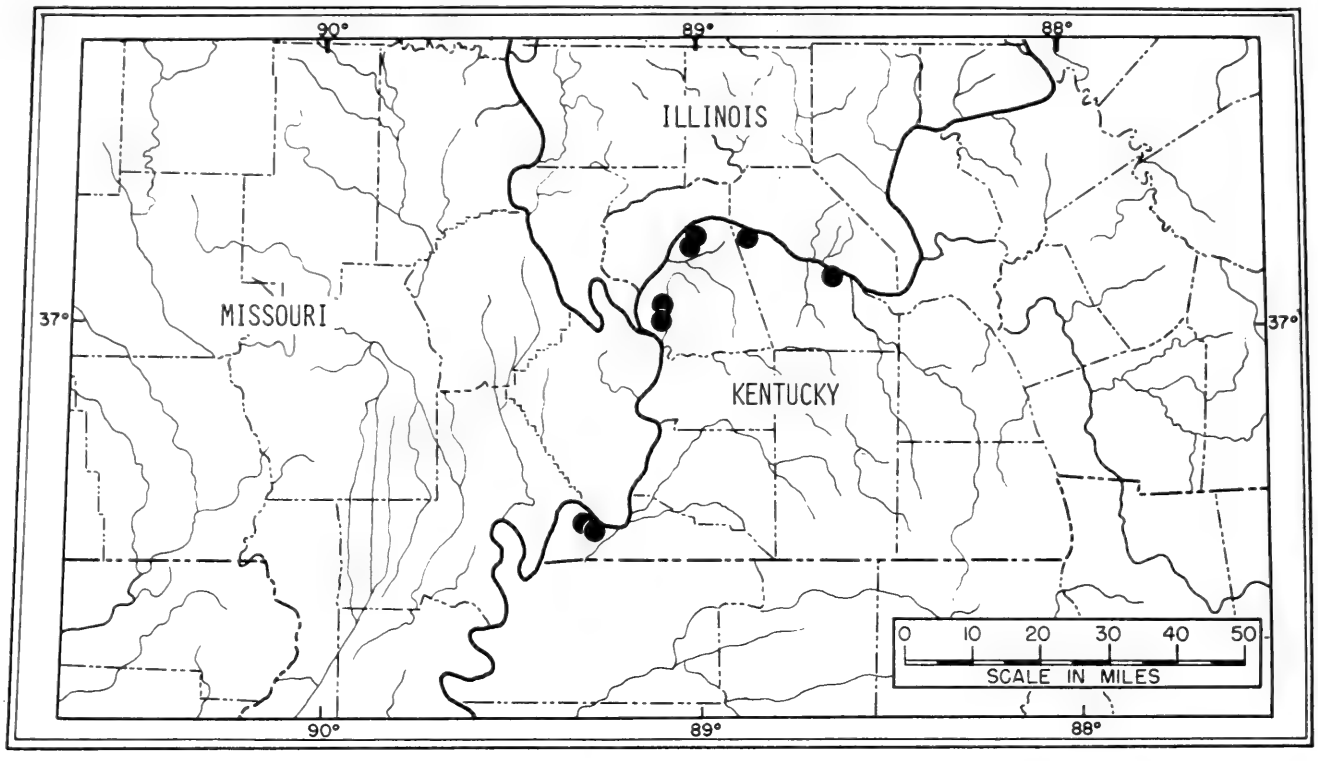

FIG. 1. Known localities from which *Notropis maculatus* has been collected in Kentucky. The southwestern records are those reported by Sisk (1973). The Ohio River oxbow localities are based on specimens reported in this paper.

was discovered spawning beneath or adjacent to a large log in water 15 to 30 cm deep. The breeding males were extremely brightly colored, with a suffusion of red over much of the body and head, in the iris of the eye, and distally on the dorsal, pelvic, anal, and caudal fins. The basicaudal black spot, the subdistal anterior black dorsal fin blotch, and the black midlateral band were all prominent (Fig. 2). Except for occasional gravid females with pale red snouts, females lacked red pigment. Small, white tubercles were variously present on the lateral snout, lower head, chin, and dorsally along the anterior rays of the pectoral fins. Breeding females were without tubercles. Florida breeding males were described as having red on the dorsal and pelvic fins and tubercles on the snout. Douglas' (1974) description of breeding males in Louisiana, "with much red on the head and body (especially the tips and edges of all fins)," is much more in agreement with the pigmentation of the Kentucky specimens.

Cowell and Barnett (1974) stated that in Florida, nonreproductive males larger than 30 mm total length could be distinguished from females by the presence in males of a "band of dusky spots along the anterior margin of the dorsal fin." This band was rarely evident on Kentucky specimens, being clearly developed only on a few males collected in August.

Although in Florida the species breeds from March to early October, with mature females and ripe males taken in every collection during these months, there is no indication of such a protracted spawning period in Kentucky. Young of the year were collected in April, and spawning individuals in May, indicating a spawning period extending at least from March to May; however, none of the individuals collected in August and September were in breeding condition.

In Florida, the number of mature ova (those over 0.8 mm in diameter) in 47 females ranged from 72 to 408 and averaged 163. In Kentucky, the number ranged from 25 to 431 and averaged 246 in 21 females collected on 28 May 1972. As in the Florida population, the largest females produced

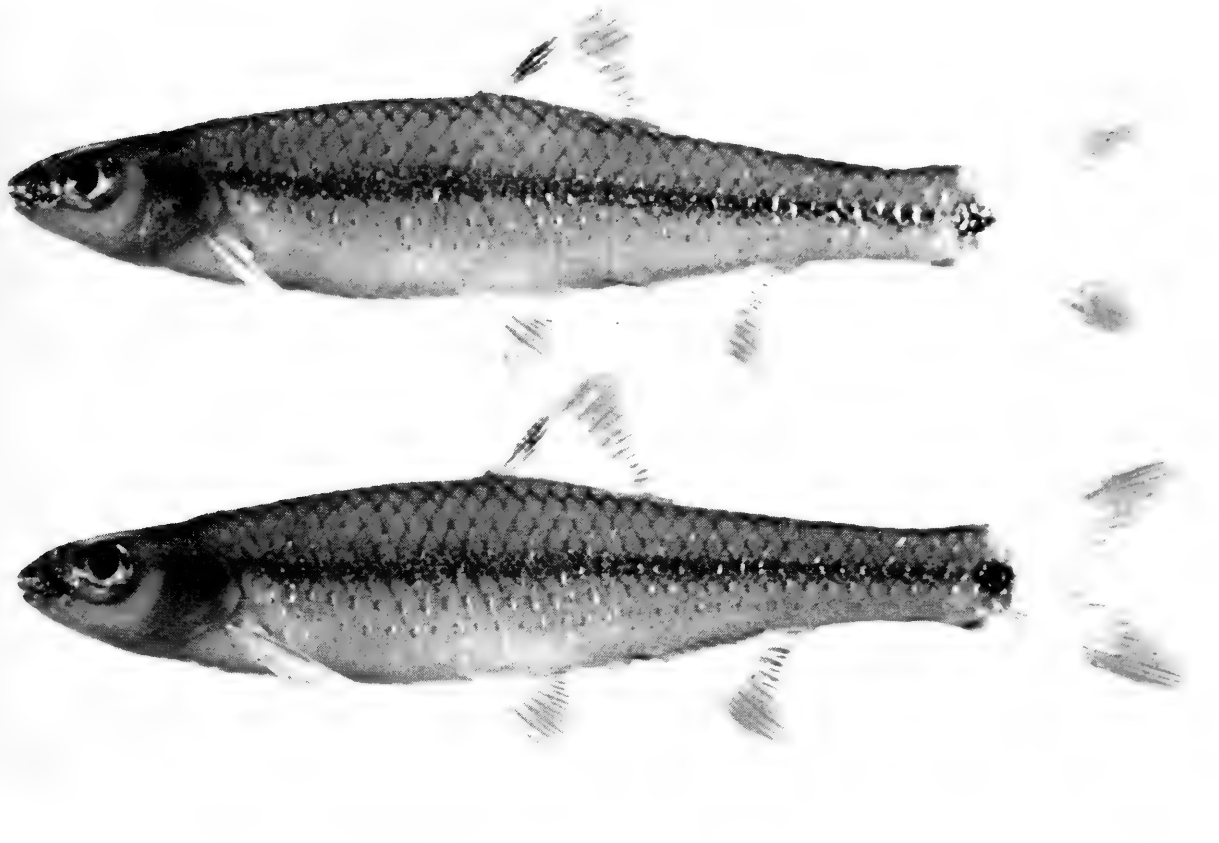

FIG. 2. *Notropis maculatus* tuberculate breeding males collected in Kentucky (Metropolis Lake, 5 km N Grahamville, McCracken Co., 28 May 1972).

the most eggs; the higher average number of eggs found for the Kentucky specimens probably was primarily a result of larger females being examined (11 of the 21 females were over 53 mm total length). The relationship between the number of mature ova (F) and the standard length (L) was $\log F = -5.808 + 5.013 \log L$, with $r = 0.53$, and between the number of mature ova and the total length (T) was $\log F = -5.105 + 4.319 \log T$, with $r = 0.47$.

The sex ratio of the 190 *N. maculatus* examined from Kentucky was 0.8 females to 1 male ($\chi^2 = 2.10$, n.s.), of the 106 specimens from Metropolis Lake was 0.5 females to 1 male ($\chi^2 = 9.66$, $p < .005$), and of the 83 specimens collected in Metropolis Lake on 28 May 1972 (the spawning school) was 0.4 females to 1 male ($\chi^2 = 18.32$, $p < .005$). Although females were found to outnumber males in Florida, males were relatively more common along the shoreline; all of our specimens were captured near shore.

As in Florida, females averaged significantly larger than males. The average total length of 22 females collected in Metropolis Lake on 28 May 1972 (range = 42.1 to 60.6 mm) was 52.7 mm, that of 61 males (range = 40.9 to 60.3 mm) was 48.6 mm ($t = 4.16$, $p < .005$). All were mature individuals and apparently about 1 year old. Although these averages are larger than those given for mature *N. maculatus* in Florida (mean total length for females = 44.4 mm, for males = 41.6 mm), younger fish may have been included in the Florida sample. The average standard length of the Kentucky females was 42.0 mm (range = 33.7 to 48.1 mm), of males was 39.6 mm (range = 32.6 to 47.8 mm). The largest specimen examined from Kentucky was a 48.1-mm SL, 60.6-mm TL female.

No annulus formation was discernible in Florida. In Kentucky, a weak annulus was visible on some individuals but aging by this method was not feasible. However, it

TABLE 1.—STANDARD LENGTH FREQUENCIES OF *NOTROPIS MACULATUS* COLLECTED IN OXBOW LAKES IN KENTUCKY

Standard Length, mm	Month of Collection			
	Aug	Sep	Apr	May
48				2
46				3
45				3
44				5
43				3
42				8
41				7
40				11
39			1	7
38				14
37				6
36			1	7
35				4
34		2		2
33		1		1
32	1	1		
31	1	6		
30	2	8		
29	2		1	
28	11	5	1	
27	4	1		
26	13			
25	21			
24	10			
23	4			
22	3			
21	2	1	1	
20	1			
19	1	1		

appears from the size distribution of the specimens collected (Table 1) that the species lives a maximum of less than 2 years in Kentucky as well as in Florida.

ACKNOWLEDGMENTS

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LITERATURE CITED

COWELL, B. C., AND B. S. BARNETT. 1974. Life history of the taillight shiner, *Notropis maculatus*, in central Florida. Amer. Midl. Nat. 91:282–293.

DOUGLAS, N. H. 1974. Freshwater fishes of Louisiana. Claitor's Publ. Div., Baton Rouge, La. 443 pp.

PFLIEGER, W. L. 1971. A distributional study of Missouri fishes. Univ. Kans. Publ., Mus. Nat. Hist. 20:225–570.

———. 1974. Fishes. *In*: F. T. Holt, J. F. Keefe, W. H. Lewis, W. L. Pflieger, and M. H. Sullivan (eds.). Rare & endangered species of Missouri. Mo. Dept. Cons., U. S. Dept. Agric., Soil Cons. Service n.p.

SISK, M. E. 1973. Six additions to the known piscine fauna of Kentucky. Trans. Ky. Acad. Sci. 34:49–50.

The Probability of Annual Extreme Winter Temperatures in Kentucky

Jerry D. Hill
National Weather Service, Office for Agriculture, University of Kentucky,
Lexington, Kentucky 40506

Abstract

The minimum winter temperatures were examined for several different locations in Kentucky having long periods of record. The cumulative frequency distribution of the temperatures was compared with the normal and the Fisher–Tippett Type I extreme value distributions to determine which provided the best approximation to the data. The Kolmogorov–Smirnov test for goodness of fit did not allow either distribution to be rejected at the .10 probability level.

Further tests were made for asymmetry in the data using the coefficient of skew. Five locations tested failed to exhibit significant skew at the .10 probability level which would be characteristic of the extreme value distribution. In the absence of significant skew, the normal distribution was then selected for use in the estimation of temperatures to be expected for various return periods. Observed temperatures from 33 locations were used to estimate the parameters of the normal distribution for each and predict coldest temperatures to be expected with return periods of once in 2, 5, 10, 25, 50, and 100 years.

Introduction

An analysis of the probability of extreme winter temperatures has far-reaching implications for anyone involved in long-range planning. The agriculturist must select varieties of winter grain or fruit trees for their ability to withstand a particular degree of cold. Builders must be able to anticipate the extent of cold their structures will have to withstand and still provide a measure of comfort. The coldest temperature ever recorded at official observing stations in Kentucky, –37 C at Cynthiana and at Bonnieville in Hart County, may be an extremely rare event or it might be expected to occur several times in a normal lifetime. A study of the record of extreme cold temperatures can reveal the frequency of occurrence of any particular value.

The climate of Kentucky is characterized by 2 factors which determine the coldest temperatures usually experienced during the winter season. The first is the movement of cold air masses across the state which provide the conditions necessary for occasional frigid readings. The second is a more local factor characterized by the state's irregular terrain, which allows uneven nighttime cooling and the drainage of cold air into low-lying areas. Because of the local effects, it is difficult to generalize and assume the coldest temperatures will always occur in the northern portions of the state or in the higher elevations of the eastern sections. The probability of extreme values must be investigated separately for each location where temperatures have been recorded.

Source of Data

Climatological weather observing stations in Kentucky have been established by the National Weather Service for the purpose of gathering daily temperature data at about 80 locations and rainfall data at about 180 locations. The instruments are installed either at the home of a volunteer observer or at a cooperating organization such as a water plant, radio station, etc. Maximum and minimum thermometers are read once a day in order to determine the extremes during the preceding 24-hour period. These thermometers are mounted inside a standard, ventilated instrument shelter at a height of 5 feet above a grass surface. While sites are selected to minimize any modifying influences, the location may occasionally be near a body of water or prone to cold air drainage.

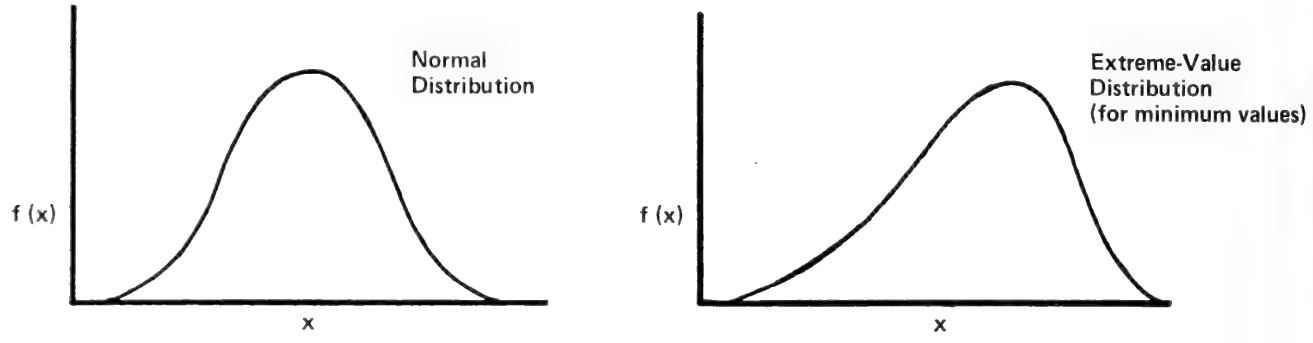

FIG. 1. Comparative shape of normal and extreme value frequency distributions.

A total of 33 well-distributed temperature observing stations were chosen for this study, all of which have periods of record extending from 20 to more than 75 years. The coldest single temperature reached during each year was used to define a set of extreme temperature observations for the period of record at every location.

METHODS

In any study of probability, it is necessary to find a theoretical frequency distribution which represents the data under consideration. In a study of extreme temperatures in Ohio (Miller and Weaver 1970), the well-known normal distribution was used to prepare tables of temperatures occurring at selected probability levels. In many design problems where annual extremes are being considered, the Fisher–Tippett Type I extreme value distribution (Thom 1966) has been widely used. While the normal distribution is symmetrical with equal probability on either side of the mode, the extreme value distribution is skewed and, in the case of minimum values, has a greater probability of values below the mode than above (Fig. 1). The extreme value distribution was used to determine the probability of extreme winter temperature in Tennessee (Bailey 1965).

TABLE 1.—RESULTS OF KOLMOGOROV–SMIRNOV TESTS AT 3 LOCATIONS

Location	Length of Record	Value of D: Normal	Value of D: Extreme Value	Critical Value of D at Level .10
Greensburg	75 years	.07	.11	.139
Murray	41 years	.09	.05	.187
Beaver Dam	36 years	.06	.06	.199

To prepare tables of probabilities or return periods of extreme winter temperatures for Kentucky, it is necessary to determine which of these frequency distributions best represents the population from which the observed data have been drawn. As a preliminary test, data from Greensburg, Beaver Dam, and Murray were analyzed, and the Kolmogorov–Smirnov test (Feller 1948) applied to determine if either the normal or extreme value distribution could be rejected. In order to reject the hypothesis that the data are from a particular distribution under consideration the test requires that D, the maximum deviation between the theoretical cumulative distribution function and the sample cumulative distribution function, exceed a critical value. The value depends upon the number of observations and the level of confidence to be placed in the test. For this investigation, a rather liberal 10 percent confidence level was chosen for all statistical tests. The results of the test using both the normal distribution and the extreme value distribution functions proved inconclusive in differentiating between the two possibilities (Table 1).

Further testing was done to determine if the samples exhibited certain qualities unique to the assumed theoretical frequency distributions. An obvious test is for symmetry since the normal distribution is symmetrical with the mode, mean, and the median values equal while the extreme value distribution is asymmetrical. A useful measure of symmetry is the coefficient of skew, sk (Panofsky 1965) defined in standard statistical notation as:

TABLE 2.—RESULTS OF TESTS FOR SYMMETRY

Location	Mean	Median	Skew	t	Critical t at Level .10
Bowling Green	–17.8 C	–17.8 C	–0.258	.912	1.289
Greensburg	–19.6	–20.0	–0.335	1.184	1.289
Anchorage	–20.8	–20.8	–0.054	.190	1.289
Richmond	–18.9	–19.2	–0.083	.293	1.289
Williamsburg	–17.8	–17.8	–0.015	.053	1.289

$$sk = \frac{\sum_{i=1}^{N} (x_i - \bar{x})^3}{N\sigma^3}$$

A sample of data with more values below the mode than above will be skewed to the left and have a negative coefficient of skew. The normal distribution has a coefficient of skew equal to 0.

Tests of symmetry were made using data from 5 stations each with periods of record extending over 70 years or more. All exhibited a negative coefficient of skew, however, most of the differences from 0 were small. In order to test whether the differences were significant, a t-test was made (Snedecor 1956) where the t statistic was formed as:

$$t = \frac{sk - 0}{\text{Standard error of sk}}$$

The standard error of sk can be estimated (Brooks and Carruthers 1953) as approximately $\sqrt{6/N}$. To evaluate whether the skew is significant, the hypothesis can be formed that the data were drawn from a sample with a coefficient of skew equal to 0. If the value of t exceeds the appropriate tabled values at the selected level of significance, the hypothesis can be rejected. Table 2 gives the results of these tests.

Since the t values all fail to exceed the critical limit, the hypothesis cannot be rejected. This would imply that the normal distribution reasonably represents the population although the data for Greensburg exhibit a near significant skew at the 10 percent level.

As a further check on the distributional assumption, temperatures corresponding to various return periods were estimated using the normal and extreme value distributions, then compared to observed data. The results are shown in Table 3 where only Greensburg exhibited evidence which would question the use of the normal distribution function. In the data from Greensburg, temperatures occurring with intermediate return periods of once in 10 to 25 years agree more closely with the normal probabilities while less frequent occurrences on the order of once in 50 to 75 years are skewed considerably and favor the extreme-value distribution.

DISCUSSION

None of the data presented here provides overwhelming conclusive proof for the selection of one distribution function or the other; however, the absence of pronounced

TABLE 3.—COLDEST WINTER TEMPERATURES °C PREDICTED AND OBSERVED FOR GIVEN RETURN PERIODS. N = NORMAL, EV = EXTREME VALUE, O = OBSERVED VALUE

Coldest Temperature Reached or Exceeded One Year in:	Greensburg			Bowling Green			Anchorage			Richmond			Williamsburg		
	N	EV	O	N	EV	O	N	EV	O	N	EV	O	N	EV	O
5	–23	–23	–23	–22	–21	–21	–24	–24	–24	–23	–22	–23	–22	–21	–23
10	–26	–26	–25	–23	–24	–24	–26	–27	–26	–24	–26	–24	–23	–24	–24
20	–27	–29	–27	–25	–27	–26	–27	–28	–28	–26	–28	–26	–25	–27	–24
25	–28	–30	–27	–26	–28	–27	–28	–29	–29	–27	–29	–26	–26	–28	–25
40	–28	–32	–32	–27	–29	–29	–29	–32	–29	–28	–31	–29	–27	–29	–26
50	–29	–33	–33	–27	–31	–29	–29	–32	–30	–28	–32	–31	–27	–31	–26
75	–31	–33	–34	–28	–32	–29	–29	–33	–	–29	–33	–31	–28	–32	–28

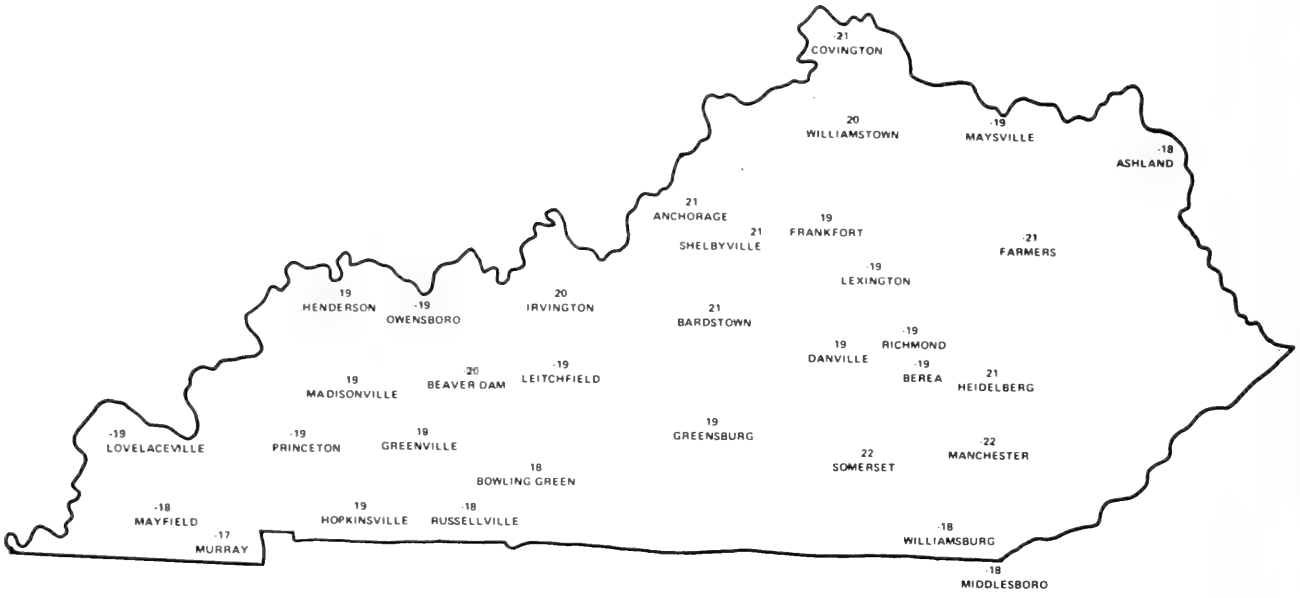

FIG. 2. Locations used in the study and their mean annual minimum temperature, °C.

skew in most sets of data favor the normal distribution. Therefore, the normal distribution has been used to estimate the coldest annual temperature expected to occur with frequencies ranging from once in 2 years (the mean) to once in 100 years for the locations shown in Fig. 2. Those temperatures are presented in Table 4.

It is interesting to note that the coldest mean annual minimum temperature among all stations shown is at Somerset, in southeastern Kentucky at an elevation of approximately 330 m. The weather instruments are located about 2 km north of the city in a broad valley favorable for cold air drainage. The observing station at Farmers has a similar exposure and also shows a tendency to favor cold temperatures.

Data from Ashland have been collected since 1916 by the U.S. Corps of Engineers at their dam on the Ohio River. The moderating effect of the large body of water is evident in reducing the temperature extremes expected at the dam. The values are slightly more temperate than those indicated for Russellville which is at approximately the same elevation but a full 2 degrees of latitude further south.

TABLE 4.—COLDEST ANNUAL TEMPERATURE EXPECTED FOR SELECTED RETURN PERIODS AT SELECTED LOCATIONS IN KENTUCKY

Location	Coldest Temperature °C Reached or Exceeded One Year in:					
	2	5	10	25	50	100
Anchorage	–21	–24	–26	–28	–29	–30
Ashland	–18	–21	–23	–24	–26	–27
Bardstown	–21	–24	–26	–28	–29	–31
Beaver Dam	–20	–24	–26	–28	–30	–31
Berea	–19	–22	–24	–26	–27	–28
Bowling Green	–18	–22	–23	–26	–27	–28
Covington	–21	–23	–25	–27	–28	–29
Danville	–19	–22	–23	–26	–27	–27
Farmers	–21	–25	–27	–29	–31	–32
Frankfort	–19	–23	–24	–26	–27	–28
Greensburg	–19	–23	–26	–28	–29	–31
Greenville	–19	–23	–24	–26	–28	–29
Heidelberg	–21	–24	–26	–28	–29	–30
Henderson	–19	–22	–24	–26	–27	–28
Hopkinsville	–19	–22	–24	–27	–28	–29
Irvington	–20	–23	–25	–27	–28	–29
Leitchfield	–19	–22	–24	–26	–28	–29
Lexington	–19	–23	–24	–26	–27	–28
Lovelaceville	–19	–23	–24	–27	–28	–29
Madisonville	–19	–23	–24	–27	–28	–29
Manchester	–22	–25	–27	–28	–29	–31
Mayfield	–18	–21	–23	–25	–26	–27
Maysville	–19	–23	–24	–27	–28	–29
Middlesboro	–18	–21	–23	–25	–26	–27
Murray	–17	–20	–22	–24	–25	–26
Owensboro	–19	–23	–24	–26	–28	–29
Princeton	–19	–23	–26	–28	–29	–31
Richmond	–19	–23	–24	–27	–28	–29
Russellville	–18	–22	–24	–26	–27	–28
Shelbyville	–21	–24	–26	–28	–29	–31
Somerset	–22	–26	–28	–30	–31	–33
Williamsburg	–18	–22	–23	–26	–27	–28
Williamstown	–20	–23	–25	–27	–28	–29

SUMMARY

The coldest temperature expected during the winter at any location in Kentucky is determined not only by the latitude but also

the topography of the location. For most locations the long-term weather records show that extreme low temperatures occur with a frequency which can be approximated by the normal distribution function. Tables of the normal distribution can be used to calculate the extreme winter temperatures expected to occur with any given frequency.

LITERATURE CITED

BAILEY, M. H. 1965. Extreme winter temperatures in Tennessee. J. Tenn. Acad. Sci. 40: 18–21.

BROOKS, C. E. P., AND N. CARRUTHERS. 1953. Handbook of statistical methods in meteorology. Her Majesty's Stationery Office. London, Eng. 412 pp.

FELLER, W. 1948. On the Kolmogorov–Smirnov limit theorems for empirical distributions. Ann. Math. Stat. 19:279–281.

MILLER, M. E., AND C. R. WEAVER. 1970. Extreme monthly and annual temperatures in Ohio. Ohio Agric. Res. Dev. Cent., Res. Bull. 1041. 35 pp.

PANOFSKY, H. A., AND G. W. BRIER. 1965. Some applications of statistics to meteorology. Penn. St. Univ., University Park, Pa. 224 pp.

SNEDECOR, G. W. 1956. Statistical methods. Iowa St. Univ. Press, Ames, Iowa. 534 pp.

THOM, H. C. S. 1966. Some methods of climatological analysis. World Meteorol. Organ., Geneva, Switzerland. Tech. Note 81. 52 pp.

Populational Differences in Survival Patterns of Sweetgum

Joe E. Winstead
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Exposure of progeny from 6 different populations of *Liquidambar styraciflua* to climatic conditions of south-central Kentucky for a 2-year period indicated different survival rates between the populations. Populations from sites of origin outside of a general latitude range of 34–37° N. Lat. showed very low survival values in a transplant garden near Bowling Green, Kentucky.

Introduction

In recent years, studies in the interactions of a species to its environment have shown that even though a species type may be morphologically identical throughout its geographical distribution, the species may show different populational patterns in regard to a population's response to the conditions of a selected habitat. In studies of plants, one of the first indications of such genetic diversity was by Turesson (1922), where reciprocal transplanting of different populations of several herbaceous species led to the development of the ecotype concept. Following his work, a multitude of experimental ecologists have documented the fact that ecotypes are populations of a species genetically adapted to a given habitat. The most recent review of scientific literature by Hiesey and Milner (1965), concerning experimental evidence of the evolution of genetically different populations of a species, indicates that selection of genetic variants of a species is the rule rather than an exception. Academically, such knowledge has been valuable in answering questions of how an organism survives in its habitat, and has led ecologists to move away from emphasis on studies of what is located where. Due to man's influence on environmental quality as well as quantity in the last few years, serious questions have arisen about conservation practices that may require answers developed from the knowledge of just how much genetic diversity is present in a species type. It is the purpose of this report to show that experimental knowledge of ecotypes in a species type may be utilized in a practical application to show the value of retention of populational diversity.

Acknowledgments

Special thanks are due Dr. R. D. Williams, Jr., who aided in the planting of the various populations.

Materials and Methods

From January to March 1969, 1-year-old seedlings of sweetgum *Liquidambar styraciflua* were supplied by Forestry Departments of Ohio, Illinois, North Carolina, Kentucky, Mississippi, and Louisiana. Upon arrival in the labortory, the packaged seedlings were stored in the dark in a cold room maintained at a constant temperature of 4 C to prevent bud bursting before planting. The various forestry departments indicated the source of the seeds from which the seedlings were germinated and it was found that the material from North Carolina was grown from seeds collected from trees at an unknown site in Tennessee. In March 1969, the seedlings were removed from the cold chamber and planted in a level plot provided by the University Farm. Twenty seedlings of each population (with the exception of the Kentucky material where only 18 seedlings were available) were planted in rows with a distance of 1 m separating each row and each seedling. Upon planting, each seedling was watered and native grasses removed in the vicinity of the plant. Seedlings were periodically watered until the end of April, at which time it was felt that the seedlings were sufficiently estab-

lished to begin the survival test. Observations were made on the test plot over the next 2 years, and the test was terminated when indiscriminate spraying for thistles in the area on 19 May 1971 seriously damaged the surviving trees.

RESULTS

By 30 September 1969, a general trend of survival by seedling populations whose origins were between 34 and 37° N latitude was evident (Table 1). The populations from Mississippi and Louisiana showed the lowest survival value during that time. A frost on 31 March 1969 (low –6 C) caused severe damage to the stem tips of the 2 southern populations, but the seedlings later showed partial recovery, and leaves were produced on the lower portions of the stems. After a very wet June (28.2 cm rainfall), followed by a very dry July with rainfall of only 4.03 cm, only 2 seedlings each of these populations survived. The Ohio population seemed to also be affected by the dry month. Only the Illinois, Tennessee, and Kentucky populations showed survival patterns of 50 percent or more during the first growing season in the transplant garden. A similar pattern was observed during 1970, and when the program was terminated in 1971, 27 seedlings of the original 58 planted from Illinois, Kentucky, and Tennessee had survived.

Other very subtle differences between the seedlings that survived were apparent in the falls of 1969 and 1970. By mid-October 1969, the seedlings from Ohio, Illinois, Tennessee, and Kentucky were showing some fall coloration patterns in their leaves; but the 4 surviving plants from Louisiana and Mississippi were still green. The next year, noticeable coloration differences were not apparent, but surviving populations from Tennessee and northward were noticed to exhibit patterns of leaf fall in November before the seedlings from Mississippi and Louisiana. Also in 1970, the surviving seedlings from Ohio were the first to show evidence of dormant terminal buds, where bud scales had formed in those seedlings by the last week in July. By the first week in September 1970, the Illinois and Tennessee seedlings were 65–70 percent dormant, but the seedlings from Kentucky, Mississippi, and Louisiana had not shown evidence of forming dormant apical buds.

TABLE 1.—SURVIVAL PATTERNS OF TRANSPLANTED SWEETGUM SEEDLINGS

Population	Latitude of Origin (°N)	Number Planted	Percentage Survival		
			30 Sep 1969	30 Sep 1970	19 May 1971
Ohio	39.5	20	35	10	10
Illinois	37	20	50	50	50
Kentucky	36.5	18	94	55	50
Tennessee	34–36	20	70	45	40
Mississippi	31	20	10	10	10
Louisiana	31.5	20	10	5	5

DISCUSSION

The results demonstrated by this survival test indicate greater coherence and similarity of those populations whose origins were in similar habitats. The Illinois, Kentucky, and Tennessee populations are adapted to growing conditions similar to those in the Bowling Green area in relation to length of growing season and annual climatic cycles. Those populations from Mississippi and Louisiana have a naturally longer growing season (approx. 235) than the usual frost-free period of south central Kentucky (approx. 204). It is the adaption to such a longer growing season that probably resulted in later leaf coloration, leaf fall, and dormant bud formation of the more southern populations in this test, although the low survival of those populations does not allow such a statement to stand unchallenged. The low survival value of the Ohio population also poses the question of why an organism adapted to a shorter growing season (approx. 170 days) would not flourish if subjected to a longer growing season. Laboratory experiments of *Liquidambar* under controlled and uniform growing conditions by the author (1968 unpublished doctoral dissertation, University of Texas, Austin, Texas) and by Williams and McMillan (1971), where seedling progeny from the full range of geographical distribution of this species was tested, showed that seedlings from more northern provenances were

more sensitive to cooler temperatures and shorter photoperiods. This could account for the demonstration of the surviving Ohio seedlings showing earlier dormant bud formation as the photoperiod in Kentucky would be shorter during the growing season than in Ohio. Although this test involved only seedlings from 6 different locations, it confirms the results of the previous works, and is an indirect reflection of the effects of natural selection upon different *Liquidambar* populations, ensuring survival of the species in various habitats.

Such a practical demonstration as this would seem to be obvious when involving populations of plant species that have been demonstrated under laboratory conditions to be composed of ecotypes. The question is raised of just how important such knowledge is. Recently, Odum (1970) has suggested that biotic diversity of ecosystems is important in maintaining physical stability. It would seem that the diversity present in different populations of the same species type is equally important in the maintenance of the species when it has widespread distribution. An important conservation practice could well be to ensure that sufficient genotypes of a species are maintained to assure their replacement or reestablishment in areas that have been or will be disturbed by man. It is evident from the simple survival test shown here that large reserves of sweetgum in Mississippi and Louisiana would not ensure the successful replanting of such a species in more northern areas if needed. The evolution of populations of species like *Liquidambar* to specific habitat requirements has required hundreds if not thousands of years. As more and more natural resources are removed, there may be the danger of removing ecotypes that would not be easily replaced. It is hoped that as more knowledge is gained through ecological studies of species interactions with environmental parameters, logical and practical applications can be made with such information.

LITERATURE CITED

HIESEY, W. M., AND H. W. MILNER. 1965. Physiology of ecological species. Ann. Rev. Plant Physiol. 16:203–216.

ODUM, E. P. 1970. The strategy of ecosystems development. Science 164:262–270.

TURESSON, G. 1922. The species and the variety as ecological units. Hereditas 3:100–113.

WILLIAMS, G. J., AND C. MCMILLAN. 1971. Phenology of six United States provenances of *Liquidambar styraciflua* under controlled conditions. Amer. J. Bot. 58:24–31.

The Occurrence of *Cotylogasteroides occidentalis* (Trematoda: Aspidobothrea) in Kentucky

Fred H. Whittaker and Thomas R. Kozel
Department of Biology, University of Louisville, Louisville, Kentucky 40208

Abstract

The occurrence of a single specimen of an aspidobothrean trematode *Cotylogasteroides occidentalis* in a snail *Goniobasis* sp. from Oldham County is the first record of occurrence of this parasite in Kentucky.

In the fall of 1974, during the examination of 120 specimens of the prosobranch snail *Goniobasis* sp. from Harrods Creek, about 230 m east of Covered Bridge Road in Oldham County, a single specimen of a mature, but nonovigerous aspidobothrean trematode was recovered from the tissue within the spire of one of the snails. The trematode was studied alive for several hours in 0.6 percent saline, then heat killed, fixed in AFA, stained with Harris' hematoxylin, cleared in terpineol, and mounted in Euparal vert.

The specimen, 7.5 mm long and 1.5 mm wide, has 2 testes arranged in tandem in the posterior region of the opisthator or ventral sucker. The latter structure consists of 34 median and 108 marginal alveoli, and is 4.5 mm long and 1.5 mm wide. A cirrus pouch is absent, and the tubular vitellaria are predominantly lateral. These and other observed characters of taxonomic importance, as well as the specific snail host (Dickerman 1948, R. M. Cable, Purdue University, West Lafayette, Ind., pers. comm.) are considered sufficient to justify assignment of the trematode to *Cotylogasteroides occidentalis* Yamaguti, 1963.

C. occidentalis has been reported previously from *Goniobasis* sp. by Dickerman (1948) and Cable (pers. comm.). Kelly (1926) found several specimens in the freshwater clam *Lampsilis luteola*, and Nickerson (1902) initially reported the species as a parasite of the freshwater drum *Aplodinotus grunniens*.

It is noteworthy that the examination of more than 4,000 specimens of *Goniobasis* sp. and other operculate snails from Harrods Creek and other streams in Jefferson, Oldham, and Meade counties over the past 9 years has yielded only a single specimen of *C. occidentalis*.

Like a few other aspidobothrean trematodes which can become ovigerous in certain mollusks as well as in certain poikilothermic vertebrates, *C. occidentalis* can become gravid in both a snail *Goniobasis* sp. and a fish *Aplodinotus grunniens*, but primarily in the latter host (Dickerman 1948). The fish becomes infected by feeding on infected snails, but it is not known if the fish can acquire the parasite by ingesting the trematode eggs.

This report represents the first occurrence of *Cotylogasteroides occidentalis* in the snail *Goniobasis* sp. in Kentucky.

Literature Cited

Dickerman, E. E. 1948. On the life cycle and systematic position of the aspidogastrid trematode, *Cotylogaster occidentalis* Nickerson, 1902. J. Parasit. 34:164.

Kelly, H. M. 1926. A new host for the aspidogastrid trematode, *Cotylogaster occidentalis*. Proc. Iowa Acad. Sci. 33:339.

Nickerson, W. S. 1902. *Cotylogaster occidentalis* n. sp. and a revision of the family Aspidobothridae. Zool. Jahrb. Syst. 15:597–624.

Yamaguti, S. 1963. Systema Helminthum. IV. Monogenea and Aspidocotylea. Interscience Publ. Div., John Wiley & Sons, New York, N. Y. 699 pp.

A Study of the Abnormal-1 and the Poky Strains of *Neurospora crassa* for Complementation

EDWARD J. MULLANEY[1] AND DAN R. VARNEY
Department of Biology, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

An investigation to determine if 2 slow-growing cytoplasmic, respiratory deficient mutants, poky and abnormal-1, inositol, would show complementation when mitochondria carrying these mutant traits were brought together in the same cytoplasmon. To do this, it was first necessary to cross poky to an auxotroph, p-aminobenzoic acid, to obtain the double mutant, poky, p-aminobenzoic acid. Poky, p-aminobenzoic and abnormal-1, inositol were then placed on a minimal medium on which neither would grow alone, but growth would only occur as the result of the fusion of hyphae. This would determine whether a heteroplasm could be formed and whether complementation could occur at the cytoplasmic level. A series of controls were established to show if any increase in growth rate was due to heterosis between the nuclear components.

Measurement of the growth rate of the heterokaryotic homoplasmon clearly showed no increase in the growth rate, and indicated that complementation did not occur between the poky and abnormal-1 mitochondria.

INTRODUCTION

Bertrand and Pittenger (1972a) advanced a scheme for the classification of all the known extranuclear cytochrome deficient mutants in *Neurospora crassa*. This classification is partially based on the ability of members of 3 groups in this classification to show complementation only with members of another group in heteroplasmosis. This has been shown to be true in all cases investigated to date, except one (Bertrand and Pittenger 1972b). Two members of the third group, abnormal-1 and abnormal-2, have not been tested. It was the purpose of this paper to determine if there was complementation between abnormal-1 and a member of the first group (poky).

MATERIALS AND METHODS

Various media were used according to the growth requirements and the type of spore production desired. All cultures were maintained in stock on BBL *Neurospora* culture agar except for abnormal-1 which was maintained on plates of BBL potato dextrose agar. Difco *Neurospora* minimal medium with 2 percent BBL granulated agar was used for measuring growth rates and forcing heterokaryons, except where otherwise indicated. Difco Cornmeal agar (B 386) was the medium for all crosses.

The standard St. Lawrence strains of *N. crassa* 74 *A* and 77 *a*, were obtained from Dr. K. E. Papa of the University of Georgia. An auxotroph for inositol with mating type *A* was acquired from Colorado State University. The Fungal Genetics Stock Center supplied the following strains: p-aminobenzoic acid (pab-1) No. 1633 *A* and *a*, inositol (inos) No. 37401 *a*, poky (mi-1)mi-1-1.8 *a*, and abnormal-1 inositol (abn-1, inos) No. 37401 *a*. Strains, poky aminobenzoic and poky inositol, could not be obtained from any source and were produced by crossing (Mitchell et al., 1953). A poky (pab-1) mutant with type *a* mating type and a poky (inos) mutant with mating type *a* were then isolated.

The cytoplasmic genetic determinants are given in brackets, e.g., [poky], with the nuclear genotype given in parentheses, e.g., (pab-1) and therefore (pab-) [poky] would mean the strain is a nuclear mutant for aminobenzoic acid and also has the cytoplasmic poky growth trait.

A series of controls would be necessary (Pittenger 1956, Bertrand and Pittenger

[1] Present address, Department of Plant Pathology and Plant Genetics, University of Georgia, Athens, Georgia 30602.

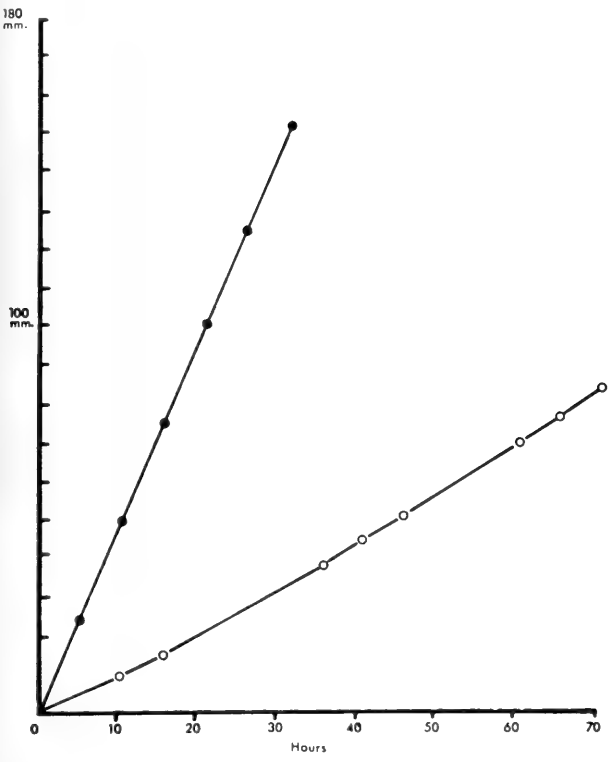

FIG. 1. The growth rates of 77 *a* (●) and (inos) [abn-1] *a* + (pab-1) [poky] *a* (○) on *Neurospora* minimal medium at 35 C.

1972b) if complementation was observed to prove it was due solely to cytoplasmic interaction.

The linear growth rate for this study was determined by growth tubes modelled after the ones used by Ryan et al. (1943) with slight modifications.

In measuring growth rates, the growth tubes were inoculated with conidia and (or) hyphae of the desired strain or strains of *N. crassa*. The growth tubes were allowed to incubate at 35 C for 24 hours and then the mycelial frontier was marked on the glass tube with a felt pen. The position of the advancing mycelial frontier was marked at regular time periods afterward, and the growth rate was measured in millimeters per hour. The normal growth rate of *N. crassa* at 35 C was determined by measuring the growth rate of 77 *a*.

RESULTS AND DISCUSSION

The growth rate for 77 *a* (Fig. 1) was 4.99 mm per hour on minimal medium. The growth rate of the heterokaryotic heteroplasmon (pab-1) [poky] *a* + (inos) [abn-1] *a* (Fig. 1) averaged only 1.44 mm per hour. This indicates that complementation occurred on the nuclear level since neither of these auxotrophs would grow on minimal medium alone, but the slow growth rate means that complementation has not occurred on the cytoplasmic level.

These results indicate that complementation between poky and abnormal-1 does not occur with the method applied in this study. This indicates that each one of these mutations does not represent a part of different mitochondrial cistrons.

While poky has shown complementation with other cytoplasmic mutants, abnormal-1 has not. The apparent failure of it to show complementation with poky in this study indicates the need to know if it will show complementation with any of the other cytoplasmic mutants.

LITERATURE CITED

BERTRAND, H., AND T. H. PITTENGER. 1972a. Isolation and classification of extranuclear mutants of *Neurospora crassa*. Genetics 71: 521–533.

————, AND ————. 1972b. Complementation among cytoplasmic mutants of *Neurospora crassa*. Molec. Gen. Genet. 117:82–90.

MITCHELL, M. B., H. K. MITCHELL, AND A. TISSIERES. 1953. Mendelian and non-Mendelian factors affecting the cytochrome system in *Neurospora crassa*. Proc. Natl. Acad. Sci. USA 39:606–613.

PITTENGER, T. H. 1956. Synergism of two cytoplasmically inherited mutants in *Neurospora crassa*. Proc. Natl. Acad. Sci. USA 42: 747–752.

RYAN, F. J., G. W. BEADLE, AND E. L. TATUM. 1943. The tube method of measuring the growth rate of *Neurospora*. Amer. J. Bot. 30: 784–799.

NEWS AND COMMENT

Annual Meeting The Annual Meeting of the Kentucky Academy of Science will be held on 7 and 8 November 1975 at the Health Sciences Center of the University of Louisville, Louisville, Kentucky. Our Academy is virtually the only unifying voice of Science in Kentucky, and as such it needs the support of every individual who believes the advancement of science is a worthwhile pursuit. The Annual Meeting affords an opportunity for scientists of a great diversity of backgrounds and disciplines to advance their individual specialties and to exchange ideas and discuss problems of mutual concern. In view of this, we call your attention to two special events to be held on Friday, 7 November in addition to the usual presentation of research findings.

1. There will be a special session Friday afternoon concerned with environmental problems in Kentucky, to be held in the Auditorium of the Health Sciences Center.

2. Dr. Theodore Fujita, Professor of Meteorology and Director of Satellite and Mesometeorology Research Projects, University of Chicago, will be the featured speaker following the Annual Banquet Friday evening at the Holiday Inn, Midtown. His subject will be Tornadoes and Severe Weather Phenomena.

In addition to these events, information will be available at the Information Desk regarding a wide variety of activities and attractions in the Louisville area.

We hope to make this the largest and most informative meeting in the history of the Academy. You can make a significant contribution through early registration, promoting the event with your colleagues, and active participation in the scientific sessions. Such a meeting is an ideal place for students to meet and mingle with each other and their teachers.

The University of Louisville takes this opportunity to offer you a warm welcome, and we look forward to seeing you at the Annual Meeting.

Charles Kupchella
John R. Meyer

Trimble County Study The Louisville Gas and Electric Company is sponsoring an environmental study of Trimble County, Kentucky, and is seeking information on all aspects of the flora and fauna of the area. If you have any such information, and wish to release it, please get in touch with Dr. Louis A. Krumholz, Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40208. Proper acknowledgment will be given. In cooperation with the U. S. Fish and Wildlife Service, the Bedford Route of the Kentucky Summer Breeding Bird Survey was established and the first formal count, sponsored by the Louisville Gas and Electric Company, was made in June 1975.

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Instructions for Contributors

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Age Structure, Growth Patterns, and Food Habits of the Southern Redbelly Dace *Chrosomus erythrogaster* in Kentucky

WILLIAM H. SETTLES[1] AND ROBERT D. HOYT
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

Various aspects of the biology of the southern redbelly dace *Chrosomus erythrogaster* were intensively studied on a population in Ivy Creek, Warren County, Kentucky from 1971 to 1972. The normal life span of the southern redbelly dace was about 2 years with a few individuals living into the autumn of their third year (26–30 months). Males disappeared from the population slightly earlier than females. Age Group 0, or individuals in their first year, constituted 76.8 percent of the total catch.

Growth in length was greatest during the first year of life while growth in weight was greatest during the second and third years. No statistically significant deviation was observed between the theoretical cubic response of growth in weight to length and that observed among the specimens in Ivy Creek.

Coefficient of condition values were greater for males than females when gonad weight was excluded, but converse results were observed when the gonads of both sexes were included in the determinations. Seasonally, condition coefficients for both sexes combined were greatest during the spawning season, lower during the warmwater months, and lowest during the cold-water months.

Food habits were generally nonspecific with combinations of algal forms (filamentous chlorophytes and diatoms), and organic detritus constituing the major gut contents. Aquatic insects were commonly found in the digestive tracts of larger specimens.

INTRODUCTION

The southern redbelly dace *Chrosomus erythrogaster* was first described in 1820 by Rafinesque from specimens collected from the Kentucky River drainage. However, since that time, little information has been reported on the biology of the species, especially in Kentucky. This paper represents an attempt to describe the age structure, growth patterns, and food habits of an isolated population of southern redbelly dace in Ivy Creek, a small springfed stream in Warren County, Kentucky.

[1] Present Address: Science Department, Saint Mary's College, Saint Mary's, Kentucky 40063.

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MATERIALS AND METHODS

Taxonomy

The taxonomy of the genus *Chrosomus* has been subject to much revision since Rafinesque's 1820 description. Confusion over the generic status of this group continues with the suggestion by Banarescu

(1964) that *Chrosomus* and *Phoxinus* are congeneric, and, since *Phoxinus* held page priority over *Chrosomus*, it should be retained. In 1970, the American Fisheries Society followed suit by formally adopting *Phoxinus* as the generic name for those species previously listed under *Chrosomus* and *Pfrille* (Bailey et al. 1970).

However, McPhail and Lindsey (1970) referred to the Canadian species as *Chrosomus eos* and *Pfrille neogaea*, and asserted that the merger of *Chrosomus* into *Phoxinus* was not warranted by existing evidence. This view is shared by G. L. Phillips, based on extensive work on both the northern and southern redbelly daces in Minnesota, who believes (pers. comm.) that *Chrosomus* should be retained until substantial data can be amassed which will cast more light upon the taxonomic status of this complex. However, because the finescale dace is somewhat different from the other species of *Chrosomus*, Phillips suggests that it be reassigned to *Pfrille*, as done by McPhail and Lindsey (1970), or possibly to *Phoxinus*.

It is our opinion that the usage of *Phoxinus* as opposed to *Chrosomus*, at least for the 3 closely related species *Chrosomus erythrogaster*, *C. eos*, and *C. oreas*, is argumentative, and that further study is needed before absolute assertions can be made regarding the North American species. In this light, the genus *Chrosomus* is retained in this study, and the southern redbelly dace shall be referred to as *Chrosomus erythrogaster*.

Habitat and Study Area

The habitat specificity of the southern redbelly dace requiring cold, springwater habitats or permanent, clear headwater streams (Forbes and Richardson 1920, Trautman 1957), has a direct influence on the distribution of the species in Kentucky. Branson (1973) stated that the redbelly dace "inhabits clear, springfed creeks in Eastern Kentucky and to a lesser extent similar streams elsewhere in the state." The species does not occur in the Tennessee River drainage in the extreme western part of Kentucky and is quite rare in tributaries of the Cumberland River in that area (Morgan Sisk 1971 pers. comm.).

Ivy Creek is a small, springfed tributary of the Green River, originating in northern Warren County, Kentucky (37°09′N, 86°25′W). It flows northwest for 7.1 km before entering the Green River. Ivy Creek is fed primarily by 2 small source streams which converge approximately 1.1 km from their origins. Numerous seepage streams also flow into Ivy Creek along its course. The stream flows through mildly karstic topography, which characterizes the region, at elevations from 160 to 164.5 m above mean sea level at its sources, to 131 m at its mouth. The average gradient is 4.73 m/km. The study area extended downstream from just below the confluence of the source streams for about 1 km.

Within the study area, Ivy Creek ranged in width from 0.9 to 3.7 m. Depths varied from 5 cm at riffles to 1 m in deeper pools. The study area was characterized by frequent riffles separating long pools of moving water, generally from 0.3 to 0.6 m deep.

During the study period, stream discharge ranged from less than 1.7 m^3/min to an observed maximum of 24.5 m^3/min. Monthly averages ranged from 0.8 m^3/min in September and October to 24.5 in February. Observed extremes in stream temperature were 5 C in December and 25 C in September. Dissolved oxygen concentrations averaged from 8 to 12 mg/1, but fell to 6.2 and 5.0 mg/1 during September and October, respectively, when the stream was choked with decaying leaf litter. pH was relatively stable with values ranging from 7.5 to 8.1. Total alkalinity and total hardness ranged from 75 to 148 mg/1 and 101 to 190 mg/1, respectively.

The Collections

The study was initiated in November 1970, with intensive sampling carried out from 5 February 1971 through 8 January 1972, and included 27 collections of redbelly dace. All collections were made by seining. A 0.3-cm mesh nylon seine was used to capture adults and a fine-meshed

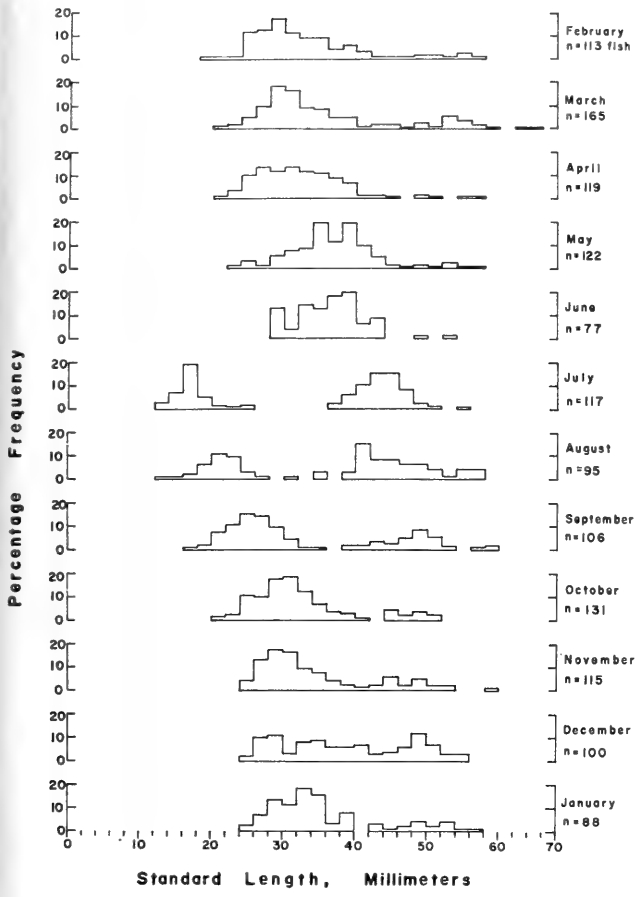

FIG. 1. Length–frequency distribution at monthly intervals for southern redbelly dace from Ivy Creek, Warren County, Kentucky, February 1971 to January 1972.

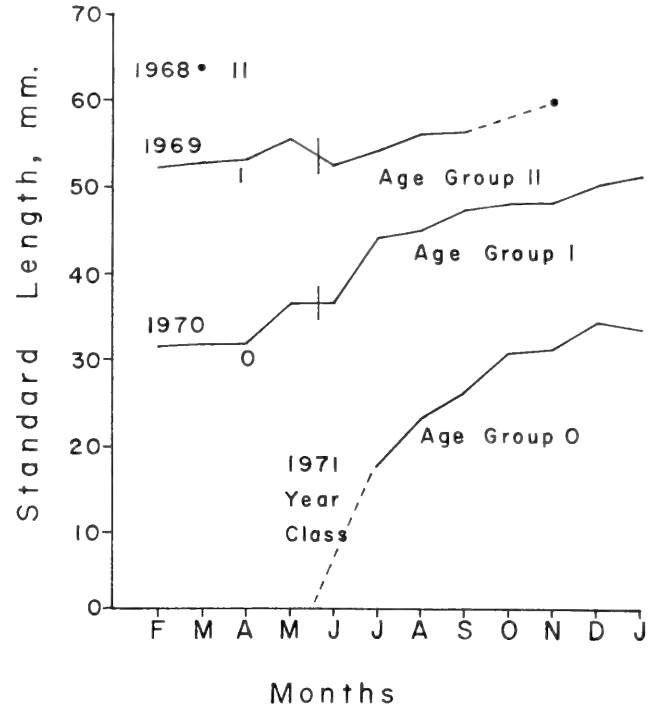

FIG. 2. Average monthly standard lengths of 3 year classes of southern redbelly dace based on measurements of 1,348 specimens from Ivy Creek, Warren County, Kentucky, February 1971 to January 1972.

seine was used in collecting young of the year. A total of 814 specimens was collected and fixed in 10 percent formalin while 534 additional dace were measured in the field and returned to the stream.

All length and weight measurements were made within 3 hours after capture. Specimens were blotted to remove excess water, weighed to the nearest 0.01 g on an electric, single-pan balance, and total (TL) and standard (SL) lengths measured using methods described by Hubbs and Lagler (1964). Standard length was used consistently throughout the study. A total to standard length conversion factor based on 225 specimens may be expressed as TL/SL = 1.23.

Length frequencies, verified by the scale method, were used to determine the age groups of 1,348 redbelly dace. Scales examined for annuli were taken between the anterior base of the dorsal fin and the lateral line series on the left side of the fish. The relationship of standard length to total body weight was determined for 864 specimens using the formula of Lagler (1956) $W = aL^n$, or $\log W = \log a + n \log L$. Length–weight data were also arranged according to sex (328 males and 350 females), and according to season of capture (spawning season, March through June, $N = 405$; warmwater season, July through October, $N = 176$; and coldwater season, November through February, $N = 283$). Methods outlined by Lagler (1956) were used to test length–weight regressions to determine the degree of adherence to the theoretical cubic response of growth in weight to growth in length. Analysis of covariance, patterned after Snedecor (1962), was used to determine any statistical differences among sexes or among specimens taken during different seasons.

The coefficient of condition (K) was calculated for each of 269 male and 322 female dace using the equation $K = W \times 10^5/L^3$.

TABLE 1.—ESTIMATED AGE GROUP COMPOSITION AT MONTHLY INTERVALS FOR SOUTHERN REDBELLY DACE FROM IVY CREEK, WARREN COUNTY, KENTUCKY, FEBRUARY 1971 TO JANUARY 1972

	Year Spawned								
	1971			1970			1969		
	Age Group	N	% Sample	Age Group	N	% Sample	Age Group	N	% Sample
Feb	–	–	–	0	102	90.3	I	11	9.7
Mar	–	–	–	0	135	81.8	I	28	17.0[1]
Apr	–	–	–	0	114	95.8	I	5	4.2
May	–	–	–	0	113	92.6	I	9	7.4
Jun	–	–	–	0	75	97.4	I	2	2.6
Jul	0	44	37.6	I	72	61.5	II	1	0.9
Aug	0	37	38.9	I	50	52.6	II	8	8.4
Sep	0	70	66.0	I	33	31.1	II	3	2.8
Oct	0	114	87.0	I	17	13.0	–	–	–
Nov	0	93	80.9	I	22	19.1	–	–	–
Dec	0	65	65.0	I	35	35.0	–	–	–
Jan	0	73	83.0	I	15	17.0	–	–	–

[1] In March, 2 specimens of Age Group II, Year Class 1968, were collected and represented 1.2% of the total sample.

To determine the effects of the gonadal component of the total weight on the condition coefficient, the K value of each specimen was calculated with gonads intact and with gonads excised.

Specimens examined for gut contents were selected randomly from collections taken throughout the study period. The entire alimentary tract was excised and the contents examined microscopically in a wet mount.

RESULTS

An evaluation of length frequency distributions indicated the presence of 2 distinct age groups in Ivy Creek, with isolated individuals representing a third age group (Fig. 1).

From February through June, Age Group 0 (spawned in 1970) represented the dominant age group in Ivy Creek and comprised 81.8 to 97.4 percent of each sample (Table 1). During the same period, Age Group I

TABLE 2.—AVERAGE MONTHLY STANDARD LENGTHS AND RANGES FOR 3 YEAR CLASSES OF SOUTHERN REDBELLY DACE, BASED ON 1,348 SPECIMENS FROM IVY CREEK, WAREN COUNTY, KENTUCKY, FROM FEBRUARY 1971 TO JANUARY 1972

	Year Spawned								
	1971			1970			1969		
	Age Group	Range (mm)	Mean (mm)	Age Group	Range (mm)	Mean (mm)	Age Group	Range (mm)	Mean (mm)
Feb	–	–	–	0	20–43	32	I	45–58	52
Mar	–	–	–	0	22–43	32	I	46–60	53[1]
Apr	–	–	–	0	22–45	32	I	52–60	56
May	–	–	–	0	23–45	36	I	48–57	52
Jun	–	–	–	0	29–44	37	I	50–53	52
Jul	0	14–25	18	I	37–52	44	II	?–56	56
Aug	0	14–36	23	I	40–53	45	II	56–58	57
Sep	0	18–35	26	I	40–54	48	II	57–61	60
Oct	0	21–41	31	I	45–52	48	–	–	–
Nov	0	25–43	32	I	45–53	50	–	–	–
Dec	0	26–44	34	I	45–56	50	–	–	–
Jan	0	25–44	33	I	46–57	51	–	–	–

[1] In March, 2 female dace of Age Group II, Year Class 1968, were captured. Their standard lengths were 63 and 65 mm, respectively.

dace declined rapidly in relative numbers and most had disappeared by June. The only Age Group II specimens represented during that time period were 2 females, 63 mm and 65 mm SL, captured in March.

In July, age group composition was altered as a result of recruitment of young-of-the-year individuals into the general population. From July through September, Age Groups 0 (recruited young of the year) and I, with very few individuals of Age Group II, were found in Ivy Creek. By October, only Age Groups 0 and I were collected. It was likely that some Age Group II individuals were present, but were so rare that none were taken.

Young-of-the-year redbelly dace were first collected in July and had a SL range of 14 to 25 mm, with a mean SL of 18 mm (Table 2). Growth among Age Group 0 individuals was rapid through October at which time lengths ranged from 21 to 41 and averaged 31 mm. Some growth occurred during the winter, but did not resume appreciably until April (Fig. 2). At the end of their first year of life (i.e., in June), redbelly dace ranged from 29 to 44 mm SL and averaged 37 mm.

Age Group I dace grew slowly and averaged over 50 mm SL at the end of the second year. Insufficient numbers of Age Group I specimens prevented an accurate determination of their mean standard length. Age Group II dace collected in September ranged from 57 to 61 mm SL and averaged about 60 mm, while a single individual 60 mm long was collected in November. The oldest Age Group II specimens were collected in March and averaged 64 mm.

The greatest absolute growth in length occurred during the first year of life with a gradual decline in the growth rate in the second and third years.

The length–weight equation yielded the following data for 3 seasonal periods in Ivy Creek

Spawning Period (March–June)

$W = 1.177 \times 10^{-5}L^{3.096}$, or log

$W = -4.9293 + 3.096 \log L$

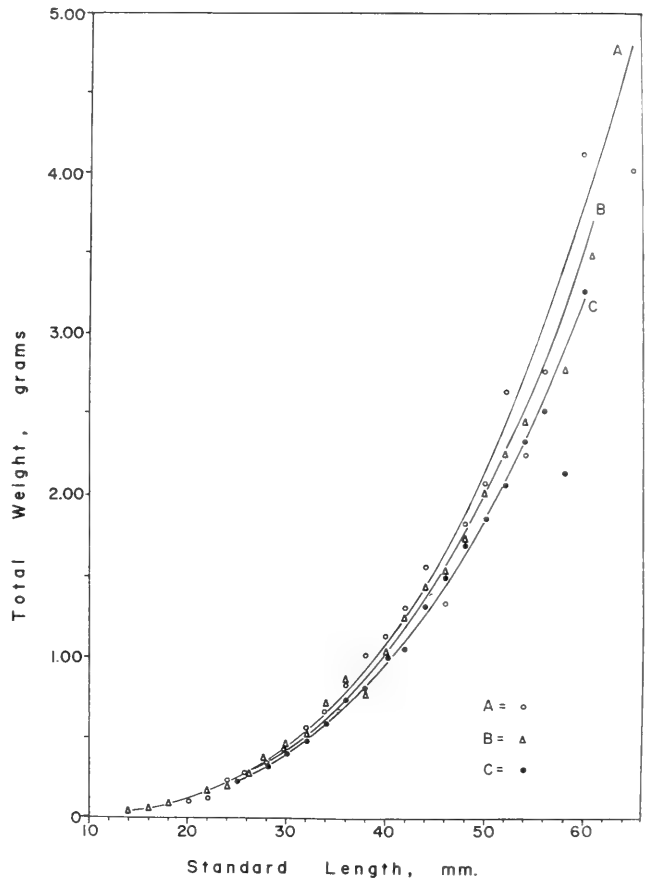

FIG. 3. Relationship between standard length and body weight of southern redbelly dace during three seasonal periods in Ivy Creek, Warren County, Kentucky, February 1971 to January 1972. A. Spawning season (March–June); B. Warmwater period (July–October); C. Coldwater period (November–February).

Warmwater Period (July–October)

$W = 1.360 \times 10^{-5}L^{3.045}$, or log

$W = -4.8665 + 3.045 \log L$

Coldwater Period (November–February)

$W = 1.457 \times 10^{-5}L^{3.006}$, or log

$W = -4.8356 + 3.006 \log L$.

An analysis of covariance revealed no significant deviation from the theoretical cubic response of increase in weight to the increase in length ($P = 0.05$) for any of the seasonal equations. However, some visually discernible differences among the 3 seasonal periods were apparent with the highest length–weight values being recorded during the spawning period and the lowest during the coldwater period (Fig. 3).

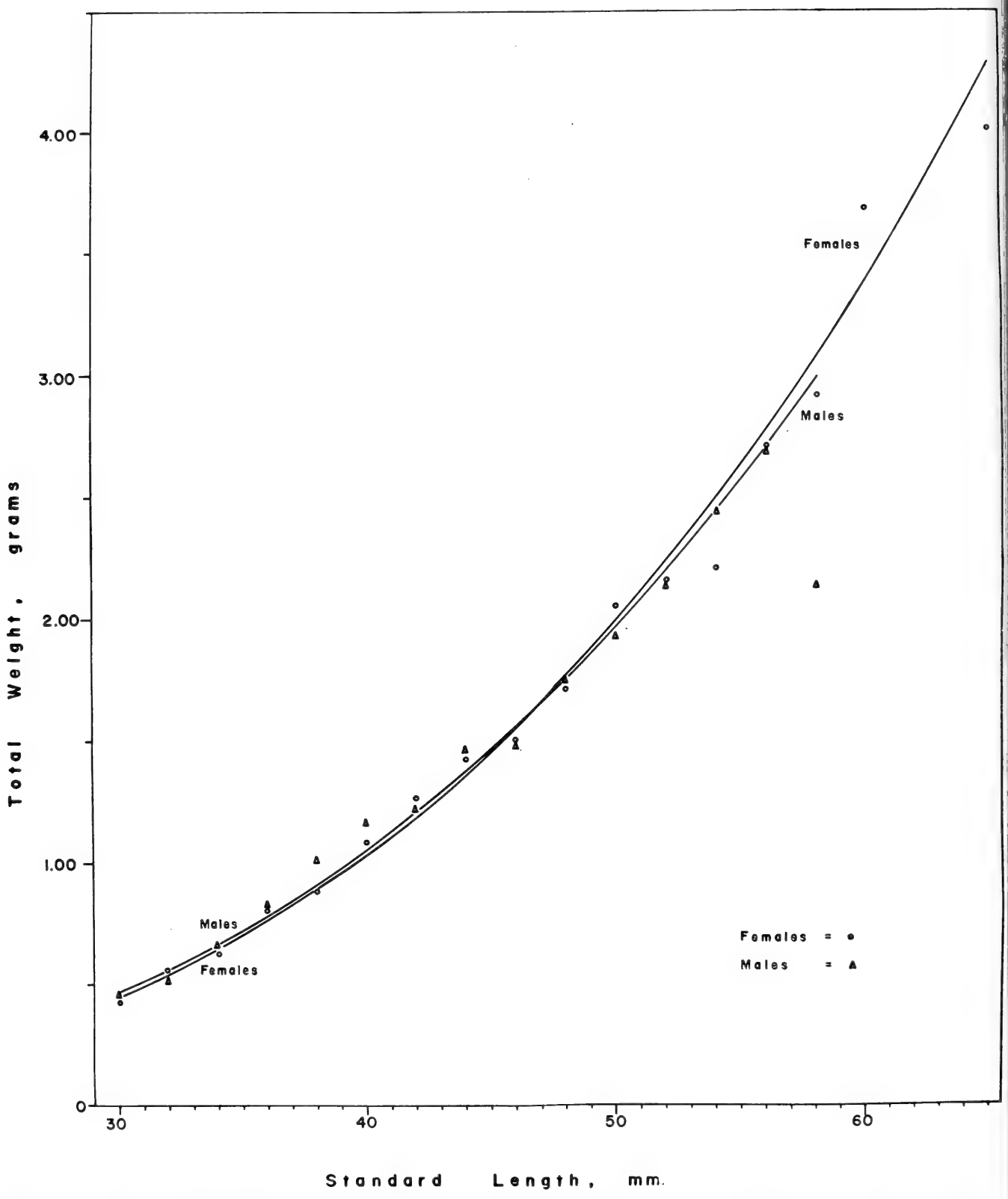

FIG. 4. Relationship between standard length and body weight in male and female southern redbelly dace from Ivy Creek, Warren County, Kentucky, February 1971 to January 1972.

Length–weight equations for each sex were as follows:

Males $W = 3.332 \times 10^{-5}L^{2.809}$, or log $W = -4.4774 + 2.809 \log L$

Females $W = 2.220 \times 10^{-5}L^{2.916}$, or log $W = -4.6537 + 2.916 \log L$.

An analysis of covariance revealed no significant deviation from the cubic re-

TABLE 3.—MONTHLY AVERAGES OF COEFFICIENTS OF CONDITION (K) FOR MALE AND FEMALE SOUTHERN REDBELLY DACE WITH GONADS INTACT AND WITH GONADS EXCISED

Month	Males		Females	
	Gonads in situ	Gonads excised	Gonads in situ	Gonads excised
Feb	1.21	1.20	1.25	1.24
Mar	1.43	1.42	1.49	1.46
Apr	1.82	1.80	1.80	1.73
May	1.80	1.78	1.84	1.73
Jun	1.75	1.74	1.70	1.59
Jul	1.56	1.56	1.51	1.49
Aug	1.69	1.69	1.64	1.61
Sep	1.57	1.56	1.57	1.55
Oct	1.65	1.64	1.60	1.56
Nov	1.61	1.60	1.64	1.59
Dec	1.54	1.53	1.51	1.45
Jan	1.58	1.57	1.57	1.52

sponse at the 0.05 level of probability. However, calculated values indicated male southern redbelly dace in Ivy Creek to be proportionally heavier than females until approximately 46 mm in standard length (Fig. 4). At that length, a reversal of the trend occurred as illustrated by the crossing of the regression line in Fig. 4.

The overall length–weight relationship for 864 southern redbelly dace from Ivy Creek was:

$$W = 1.412 \times 10^{-5} L^{3.033}, \text{ or log}$$
$$W = -4.8502 + 3.033 \log L.$$

Coefficients of condition calculated from empirical data indicated that body condition was lowest during coldwater months and immediately after spawning (Table 3). Highest K values were recorded directly prior to spawning and during the warmwater period following recovery from the spawn.

With the exceptions of February and March, males were generally more robust than females (Fig. 5). During May, females had higher overall coefficients of condition, but much of the weight component used to calculate their K values was due to the gonadal component. Condition coefficients calculated with gonads excised indicated that males were more robust than females (Fig. 5).

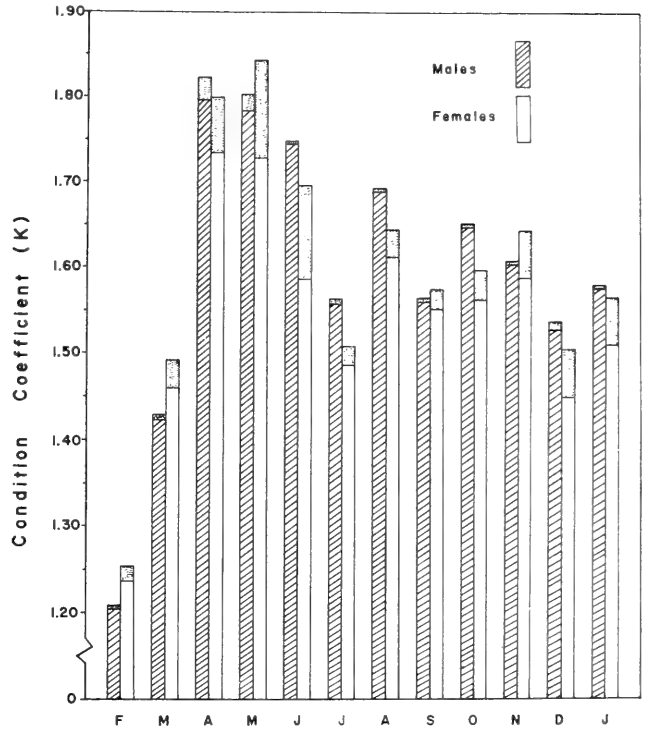

FIG. 5. Monthly averages of coefficients of condition (K) for male and female southern redbelly dace from Ivy Creek, Warren County, Kentucky, February 1971 to January 1972. Stippled bar segments represent gonadal components of total condition values.

Absolute growth in weight proceeded very slowly during the first year of life, but accelerated during the second and third years. Redbelly dace in Ivy Creek attained only 18 percent of their total weight potential during their first year of life and 34 and 48 percent during the second and third years, respectively.

Sand, silt, and detritus represented the only consistently ingested materials for southern redbelly dace in Ivy Creek. Biotic components were represented chiefly by the diatoms *Navicula* spp., *Cocconeis* spp., *Gomphonema* spp., *Nitzschia* spp., *Cymbella* spp., and *Melosira* spp. Among the specimens smaller than 35 mm SL, diatoms apparently provided the major component of the diet.

Medium-sized dace (35 to 50 mm SL) also depended heavily on microscopic foods, but midge larvae (Chironomidae) often were found in the gut contents. Larger dace, those longer than 50 mm SL, frequently ingested immature mayflies, stoneflies, and caddisflies.

From May through August, specimens of all sizes ingested large quantities of the filamentous green alga *Spirogyra*, and in some specimens, large masses of that alga filled most of the alimentary tract.

DISCUSSION

At the time of this writing, no extensive reports concerned with the age and growth of *C. erythrogaster* could be found in the literature. Trautman (1957) reported that young-of-the-year redbelly dace in Ohio ranged from 18 to 36 mm in October. Using the calculated factor of 1.23 (TL/SL), it was concluded that redbelly dace reported by Trautman (1957) ranged from 15 to 31 mm SL in October. During the present study, young-of-the-year southern redbelly dace ranged from 21 to 41 mm in October.

Trautman (1957) also reported that dace in Ohio ranged from 25 to 46 mm at the end of about a year, with standard length calculated to be 20–37 mm. Standard lengths ranged from 29 to 44 mm for year-old dace in Ivy Creek.

In regard to older dace, Trautman (1957) reported that "adults" ranged in length from 38 to 76 mm with standard length equivalents from 31 to 62 mm. Ivy Creek specimens ranged from 37 to 65 mm SL during their second and third years.

It appeared that southern redbelly dace in Ivy Creek grew somewhat faster during their first year than did their Ohio counterparts. Barlow (1961) reported that "differences between populations of a fish species are environmentally induced, unless a genetic basis can be established experimentally." He further stated that "northern representatives of a species grow slower . . . than do their southern counterparts." It is feasible then that differences in environmental factors may have resulted in variations in growth rates between dace in Ohio and those in Ivy Creek. Since length ranges for adults reported by Trautman (1957) were relatively consistent with those of Ivy Creek, it was also assumed that length maxima were comparable, though they may have been reached earlier in life among Ivy Creek representatives.

Age groups were assigned to 900 southern redbelly dace, collected on 2 occasions in Oklahoma during July by Hill and Jenssen (1968). Specimens up to 24 mm SL were assigned to Age Group 0, from 30.0 to 39.5 mm to Age Group I, and individuals 40 to 55 mm SL to Age Group II. Assignments of the Age Group 0 specimens appeared valid since they were distinct on the length frequency distribution. This range closely coincided with the 14 to 25 mm range observed for Age Group 0 specimens collected from Ivy Creek in July.

However, Hill and Jenssen (1968) used the acquisition of secondary sexual characteristics to separate Age Groups I and II, stating that dace 30.0 to 39.5 mm lacked such characteristics and were thus representatives of Age Group I. Individuals 40 mm SL and longer were sexually mature and were thus designated to Age Group II. This criterion was invalid for dace in Ivy Creek because most Age Group I fish were sexually mature and ranged to 50 mm in July. This might also have been applied to specimens studied by Hill and Jenssen because they lacked long-range length frequency data on which to base their conclusions.

It was observed that Oklahoma and Ivy Creek representatives of *C. erythrogaster* acquired secondary sexual characteristics at approximately the same lengths (39–40 mm SL) and had comparable size ranges for young-of-the-year specimens. It was thus concluded that rates of growth and maturation followed the same chronological sequence for Oklahoma and Ivy Creek southern redbelly dace.

Length–weight data revealed that southern redbelly dace in Ivy Creek adhered statistically to the cube law, or the tendency to acquire weight in proportion to the cube of length. There were no statistical differences in cubic regressions among the 3 designated seasonal periods, or between the sexes. However, it was observed that specimens were generally more robust during the spawning period due to gonadal de-

velopment. Specimens collected during the warmwater period were proportionally heavier than those collected during the coldwater period. That difference may be attributed to the availability and acquisition of food, which varied greatly between the 2 latter seasonal periods.

Coefficients of condition reflected the length–weight relationships. Values were highest during the spawning season for both sexes and for both somatic and overall condition. Condition declined sharply immediately after spawning and then recovered during the warmwater period. Somewhat lower conditions were observed during the coldwater period.

Though the length–weight relationships between males and females were basically similar, it was observed that males were slightly heavier bodied until standard lengths greater than about 40 mm were attained. At such lengths, females tended to overtake the males and become heavier proportionally. Because sexual maturity occurred at approximately 39 mm SL, it was concluded that increase in ovarian development accounted for the apparent reversal in the length–weight relationships between males and females. With few exceptions, males were more robust than females.

Feeding behavior among dace in Ivy Creek appeared to have been a nonselective ingestion of sand and silt which contained algae and nondescript bits of organic material, as well as some predation on insects. This was consistent with the findings of Forbes and Richardson (1920) who stated that, among specimens collected in Illinois, food "... is evidently obtained by nibbling or sucking the surface slime from stones and other objects on the bottom. It consists ... mainly of mud containing algae ..." Similar observations were recorded by Phillips (1969).

Because of the tendency toward random, nonselective feeding behavior, it might be expected that materials ingested by dace should have reflected that which was available in the stream at the time of capture. Our collections indicated that algal forms most frequently found among the gut contents of southern redbelly dace in Ivy Creek were also most abundant in the stream. Phillips (1969) reported that *Navicula* was the most abundant dietary component for redbelly dace in Minnesota. This was also the case for specimens from Ivy Creek. Similarly, Phillips (1969) reported *Gomphonema* and *Nitzschia* to be frequently found in the diets of dace, as was the case for Ivy Creek specimens.

From May through August, *Spirogyra* was used extensively as food by southern redbelly dace in Ivy Creek. Records for that period indicated that the appearance of that alga in the diet coincided with its profuse growth along the stream's edge. In regard to the utilization of *Spirogyra* as food, Phillips (1969) found it to be "nutritionally unimportant to *C. erythrogaster* in the stream" but that it was "readily eaten in aquarium experiments." During periods of abundance, *Spirogyra* formed a significant component of the diet for redbelly dace in Ivy Creek.

Cladophora, another green alga, grew abundantly in Ivy Creek, but was rarely found in the diet of redbelly dace. Phillips (1969) stated that this alga was eaten by *C. erythrogaster* in Minnesota "... only when starved and when no other food was present." This he attributed to the rough texture of *Cladophora* and its thick-walled cells.

Faunal components of the diet of dace in Ivy Creek included immature forms of various aquatic insects. When only fragments of such forms were observed in the guts of specimens, it was difficult to tell whether the entire insect had been eaten or if those fragments had been passively ingested with silt and sand. However, on some occasions, entire bodies of aquatic insects were found partially digested in the alimentary tracts of dace. The size of the fish appeared to dictate the size of the food item consumed. It was assumed that such insects were actively pursued and ingested. Needham (1908) reported that *C. erythrogaster* in New York actively preyed upon midge larvae.

LITERATURE CITED

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A List of the Common and Scientific Names of Fishes from the United States and Canada. 3rd Ed. Amer. Fish. Soc., Spec. Publ. No. 6. 150 pp.

BANARESCU, P. 1964. Fauna Republicii Populare Romine (Pisces-Osteichthyes). Acad. Republ. Pop. Romine, Bucuresti. XIII:336–337.

BARLOW, G. W. 1961. Causes and significance of morphological variation in fishes. Syst. Zool. 10:105–117.

BRANSON, B. A. 1973. Seldom-seen Kentucky fish. Courier-Journal & Times Mag., Louisville, Kentucky, 25 February 1973:26–33.

FORBES, S. A., AND R. E. RICHARDSON. 1920. The Fishes of Illinois. Illinois Dept. Regis. Educ., Div. Nat. Hist. Survey. 357 pp.

HILL, L. G., AND T. A. JENSSEN. 1968. A meristic study of the redbelly dace, *Chrosomus erythrogaster* (Cyprinidae), from a stream in southern Oklahoma. Southwest. Nat. 13: 55–60.

HUBBS, C. L., AND K. F. LAGLER. 1964. Fishes of the Great Lakes Region. Univ. Mich. Press, Ann Arbor, Mich. 213 pp.

LAGLER, K. F. 1956. Freshwater Fishery Biology. Wm. C. Brown Co., Dubuque, Iowa. 421 pp.

MCPHAIL, J. D., AND C. C. LINDSEY. 1970. Freshwater Fishes of Northwestern Canada and Alaska. Fish. Res. Bd. Can., Bull. 173, Ottawa, Ont. 381 pp.

NEEDHAM, J. G. 1908. Report of the entomological field station conducted at Old Forge, N. Y., in the summer of 1905. N. Y. St. Mus. Bull., 124:156–248.

PHILLIPS, G. L. 1969. Diet of minnow *Chrosomus erythrogaster* (Cyprinidae) in a Minnesota stream. Amer. Midl. Nat. 82:99–109.

RAFINESQUE, C. S. 1820. Ichthyologia Ohiensis. W. G. Hunt, Lexington, Kentucky. 90 pp.

SNEDECOR, G. W. 1962. Statistical Methods. Iowa St. Univ. Press, Ames, Iowa. 534 pp.

TRAUTMAN, M. B. 1957. The Fishes of Ohio. Ohio St. Univ. Press, Columbus, Ohio. 683 pp.

Characterization of Industrial Organic Compounds in Water

Paul C. Goodley and Marshall Gordon
Department of Chemistry, Murray State University, Murray, Kentucky 42071

Abstract

Water and sediment samples were taken from the Lower Tennessee River below the Calvert City, Kentucky, chemical complex, using known sampling techniques, and analyzed for their organic content by combined gas chromatography–mass spectrometry, and by microinfrared and micronuclear magnetic resonance spectroscopy. A number of industrial organic compounds have been found to be present in the water and sediment samples that include aromatic and aliphatic hydrocarbons, phenols, aromatic acids, and esters.

Introduction

New organic compounds are being synthesized and marketed at an estimated increase of 500 compounds per year and little is known about their real effects on water supply. Recent studies by the Environmental Protection Agency (EPA) of the New Orleans water supply indicate that the presence of organics in water presents serious problems when the water supply is treated with chlorine due to the formation of potentially toxic chlorinated organics. With the continued increase in the number of new organic products being marketed, it is quite reasonable to assume that a major concern in future years will be the presence of synthetic organic compounds in water because of their toxicity, the ease with which they combine with metals to form highly toxic organometallic compounds and complexes, and for reasons similar to those in the New Orleans case.

Concern over the presence of synthetic and certain natural organic compounds in water has prompted much research related to their isolation and characterization (Keith 1972, Goodley and Gordon 1971, Burnham et al. 1972, Keith and McGuire 1972, Hites and Biemann 1972, Kleopfer and Fairless 1972, Webb et al. 1973, Harris et al. 1974). Concentration of organics from water is usually accomplished by liquid–liquid extraction (continuous or batchwise), use of a carbon filter, or more recently, by use of filters packed with macroreticular resins (Burnham et al. 1972). Gas chromatography is usually used to separate the organic components within the concentrated extract. Volatile organics may be purged from aqueous solutions using an inert gas or organic-free air onto a porous polymer trap and subsequently desorbed and analyzed by gas chromatography (Bellar and Lichtenberg 1974). Characterization is achieved by mass spectrometry, infrared and nuclear magnetic resonance spectroscopy.

This report describes the use of a GC/MS system for "on-the-fly" identification of organics in water and sediment samples. The use of a heated adapter for the gas chromatograph permitted collection of components from the GC for subsequent (batchwise) analysis by Micro-IR and Micro-nmr techniques. Identification of the organic compounds was based on comparisons of IR, nmr, and MS spectra with similar data from authentic samples. The quantitative results were obtained by gas chromatography.

Acknowledgment

Acknowledgment is made to the Department of Commerce, "NOAA," National Marine Fisheries Service for support of this work under Public Law 88-309, Project 4-48-R. The authors wish to acknowledge partial support from the Committee on Institutional Studies and Research, Murray State University, Murray, Kentucky. The authors wish to thank Mr. Charles E. McMillen for construction of the heated collection adapter.

Materials and Methods

Isolation Procedures

The methods used for isolation of organic compounds from water and sediment samples were as follows:

Small samples (200 ml) of river water were obtained by using a nonmetallic Kemmerer Water Sampler (Wildlife Supply Company, 2200 S. Hamilton Street, Saginaw, Michigan 48602). The samples were extracted with equal volumes of distilled-in-glass organic solvents, such as chloroform, hexane, and diethyl ether. Extraction, in some cases, was accomplished by vigorous mixing of the pure solvent and water sample in a closed container by means of a magnetic stirrer for periods of time ranging from 30 min to 12 hours. The Teflon extraction impeller and procedure used was analogous to that reported by Kawahara et al. (1967). At other times, extraction procedures similar to those reported by Webb et al. (1973) were used. Following extraction, the solvent layer was separated from the aqueous layer, and the excess solvent evaporated at room temperature to an oil. Known quantities (50–100 μl) of a pure solvent were added to the residual oil and the resulting solution used for analysis by gas chromatography. Using the procedure of (1) procurement of a number of small water samples, (2) extraction with a pure organic solvent, (3) analysis of the extracts by gas chromatography, and (4) subsequent integration of the GC peaks using a digital integrator to arrive at total extractable organics, it was possible to locate the "fan" or more concentrated areas of organic pollutants in the river.

Larger and more concentrated samples (up to 38 l) of water were used and extracted in some cases by means of a continuous liquid–liquid extraction procedure in order to obtain sufficient quantities of extract for a separation of organics according to solubility classes prior to analysis by gas chromatography (Kahn and Wayman 1964).

The majority of water sampling was performed with the use of carbon filters. The procedures used are those developed and documented by EPA (Breidenbach et al. 1966). In addition to the actual sampling procedures and handling of the carbon filter, the method used by EPA for "work-up" of the extract including separations based on qualitative organic solubility scheme was followed. One variance from the EPA procedure came during the drying of the contents of the carbon filter. A flow of extremely dry air (via a drying train assembly), free of any organic materials, through the carbon filter itself was used. Since the contents of the filter can be dried at room temperature in a reasonable period of time and free from contamination from the surroundings and/or contents of other filters, this method had some definite advantages over the method described by EPA. After drying, the contents of the filter were transferred to a Soxhlet extractor and extracted with chloroform and ethanol. The extracts were separated into solubility classes according to published procedures (Breidenbach et al. 1966).

Sediment samples (2.3–34.0 kg) were obtained from the river bed by means of a Petersen sampling device (Wildlife Supply Company). A typical "work-up" procedure of the sediment samples was as follows. Six hundred milliliters of wet sediment were mixed with 1 liter of distilled water. In many cases it was necessary to separate insoluble foreign materials from the sediment–water mixture by pouring it through a screen (16 mesh). The sediment–water mixture was extracted with 300–400 milliliter portions of pure solvent by vigorous mixing using a magnetic stirrer. In order to achieve good separation of the solvent layer from the muddy water, a small amount of aluminum sulfate (~2 g) was added to and dissolved in the water–sediment mixture. This mixture was allowed to stand at 5 C for 12 hours during which time the clay particles settled to the bottom, allowing rapid separation of the solvent layer from the aqueous one. After separation, the solvent extracts were allowed to evaporate slowly and subsequently categorized according to solubilities based on the scheme used for the extracts from the water samples. It is interesting to note that the sediment samples yielded in some cases several times the amount of synthetic organic material that could be obtained from similar amounts of water.

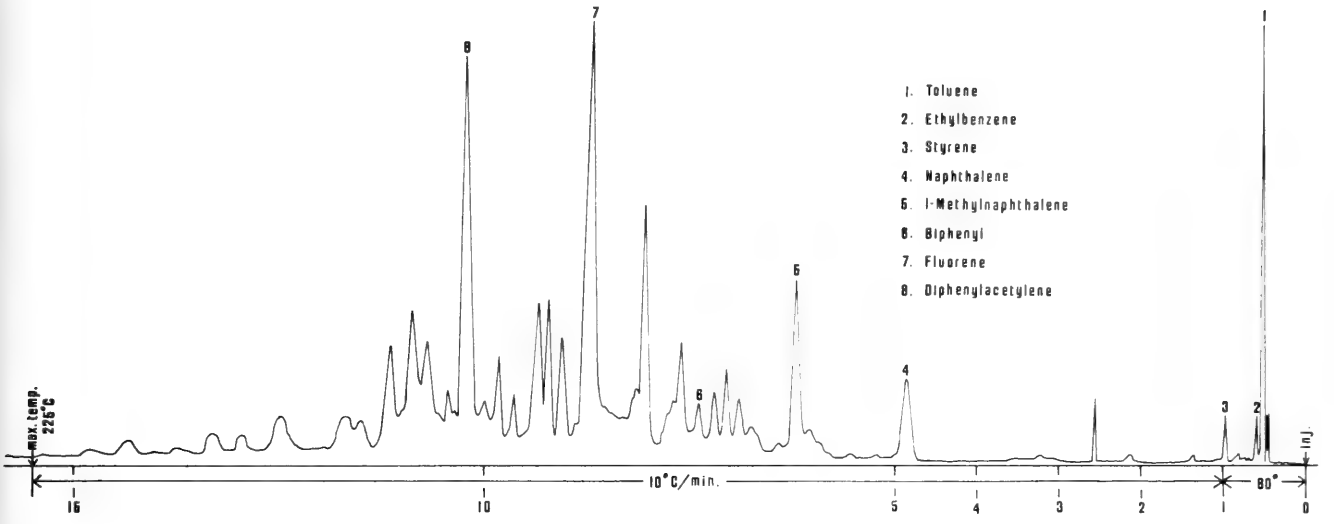

FIG. 1. Typical gas chromatogram of aromatic fraction of organic extract.

Apparatus

Most of the GC separations were achieved using a Varian, Model 600-D, equipped with a hydrogen FID and a Varian, Model 1520-C, equipped with dual FID and TC detectors. Modifications of each instrument which permitted better separations have been described previously (Goodley and Gordon 1972a, Bayer et al. 1972). Another GC, Perkin-Elmer, Model 990, was used in conjunction with the MS analysis. The initial GC analyses were performed, using a 0.010 in × 100 ft (0.025 × 3050 cm) S.S. capillary column of the open tube type. The liquid phase was FFAP. Considerable difficulty in achieving good separations, short life of the columns, and long retention times, forced the authors to search for other columns. A packed column, 0.125 in OD, 0.093 in ID × 7 ft (0.32 cm OD, 0.24 cm ID × 213.36 cm) S.S. containing 3 percent FFAP on Chromosorb W-DMCS 60/80 mesh was chosen to be best, after testing several other liquid phases and supports including teflon supports. The column support was coated, using the "minimum solution technique," and dried, using a fluidized drier (Goodley and Gordon 1972b). The recording equipment was a Honeywell Brown, Model 15, 0-1 mv unit. All retention data were obtained through the use of an Infotronics, Model CRS-104, digital integrator.

Mass spectrometry data was obtained, using Perkin-Elmer, Model RMS-4 and Model RMU-6, instruments in conjunction with Perkin-Elmer, Model 990, gas chromatographs. Using these instruments, one could scan 50 or so components in the complex mixtures, using only 0.5 μl to 1.0 μl injection into the GC. In cases where resolution of the GC was questioned, multiple MS scans were taken as the components eluted from the GC.

Infrared spectra were obtained, using Beckmann IR-10 and Perkin-Elmer, Model 137, spectrophotometers. Since most of the samples were collected from the GC, a microcell technique was used (Chin 1965). Compounds which eluted through the GC and the heated adapter were collected onto small amounts (10 mg) of powdered KBr and pressed into micropellets with the aid of paper inserts. nmr spectra were obtained, using a Varian A-60-A spectrometer. Collections were made directly from the GC into small sample bulbs used in the microcell assembly (Flath 1967).

RESULTS

Representative chromatograms obtained from extracts of water and sediment samples taken from the Lower Tennessee River are shown in Figs. 1–3, and compounds characterized to date from extracts of water and sediment samples are listed in Table 1. Interestingly, many of the compounds listed in Table 1 were also found in contaminated well water by Burnham et al. (1972). Also, many of the compounds were identical to those found in the New Orleans water sup-

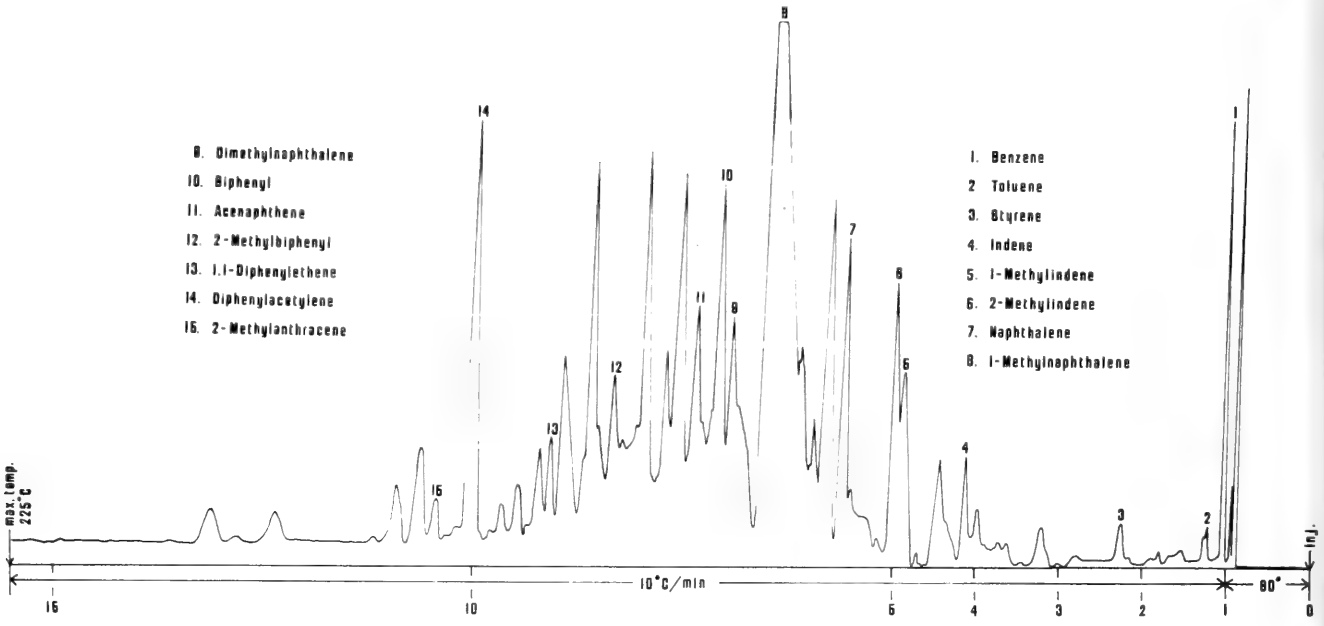

FIG. 2. Typical gas chromatogram of aromatic fraction of organic extract.

ply study. An additional 150 or so compounds have been partially identified and will be reported at a later date. Due to inadequacies in sampling procedures, the lack of a sufficient number of samples, and the absence of any significant reported data on the organic content of the area under study, the exact location of the sampling points is withheld pending a more thorough investigation of this river system. Samples were taken below Tennessee River Mile 19.0, and most of the sampling was done below the Calvert City, Kentucky, chemical complex. It is felt that the majority of the

TABLE 1.—ORGANIC COMPOUNDS IN WATER AND SEDIMENT SAMPLES FROM THE LOWER TENNESSEE RIVER, TOGETHER WITH THEIR CONCENTRATIONS (PPB)

Hydrocarbons	Concentration	Oxygenated Compounds	Concentration
3,4,4-trimethyl-2-hexene	6.0	*p*-cresol	200.0
benzene	26.1	ethylene dimethylacrylate	10.2
toluene	30.0	*o*-methoxybenzoic acid	7.8
styrene	4.2	allylbenzoate	41.8
ethylbenzene	4.0	5-chloro-2-methylbenzofuran	5.0
indene	10.0	*p*-nonylphenol	325.0
naphthalene	30.4	2,6-di-*tert*.-butyl-4-methylphenol	152.0
1-methylnaphthalene	220.0	diallyl adipate	10.0
1-methylindene	16.0	diethyl-*o*-phthalate	11.2
2-methylindene	20.2	1,2-tetradecanediol	6.2
ethylstyrene	5.0	di-*n*-butyl-*o*-phthalate	42.0
n-butylbenzene	2.1	di-*n*-octyl-*o*-phthalate	150.0
biphenyl	36.8		
acenaphthene	21.0		
fluorene	126.0		
2-methylbiphenyl	15.0		
anthracene	12.1		
diphenylacetylene	128.0		
1,1-diphenylethene	14.8		
2-methylanthracene	16.0		
4-methyldiphenylacetylene	4.0		
pyrene	5.4		
fluoranthene	7.1		
hexachlorobenzene	1.5		

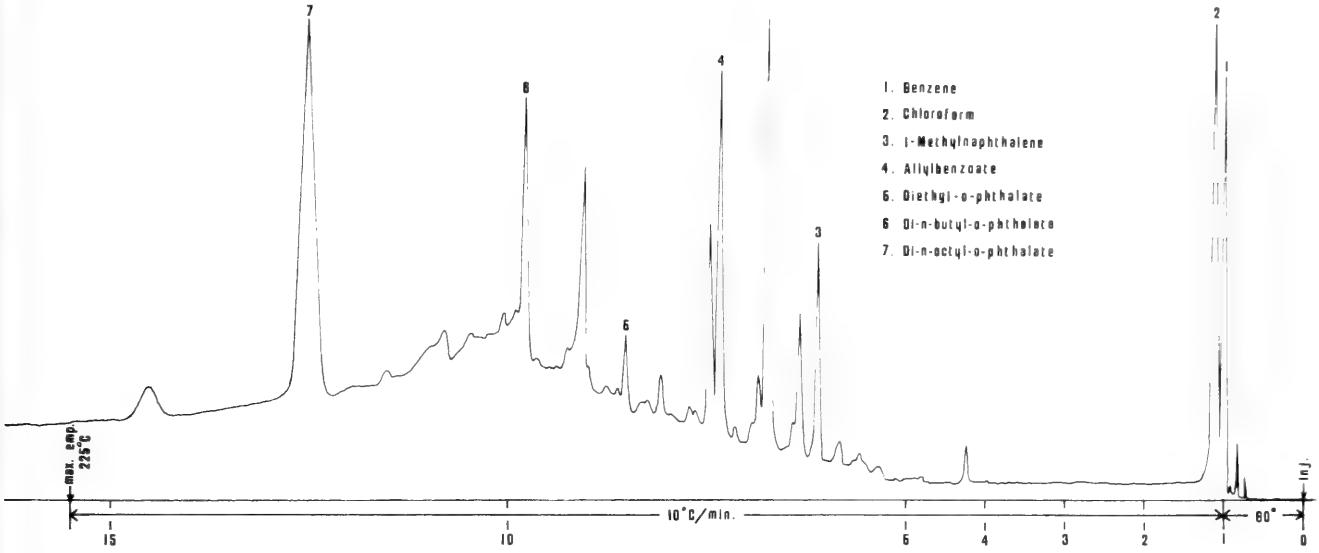

FIG. 3. Typical chromatogram of oxygenated fraction of organic extract.

organic compounds characterized to date were already present in the water prior to Mile 19.0. In some cases, the exact location of the source of the organic compounds was obtained by an examination of the extracts from mud samples taken near the industrial effluent.

LITERATURE CITED

BAYER, F. L., P. C. GOODLEY, AND M. GORDON. 1972. Rapid gas chromatographic separation of diastereomeric dichloro-butanes, pentanes, and hexanes. J. Chromatog. Sci. 10:696.

BELLAR, T. A., AND J. J. LICHTENBERG. 1974. The Determination of Volatile Organic Compounds at the μg/l Level in Water by Gas Chromatography. Methods Development and Quality Assurance Research Laboratory, U. S. Environmental Protection Agency, Cincinnati, Ohio.

BREIDENBACH, A. W., ET AL. 1966. The Identification and Measurement of Chlorinated Hydrocarbon Pesticides in Surface Waters. U. S. Dept. of the Interior, Publication WP-22.

BURNHAM, A. K., G. V. CALDER, J. S. FRITZ, G. A. JUNK, H. J. SVEC, AND R. WILLIS. 1972. Identification and estimation of neutral organic contaminants in potable water. Anal. Chem. 44:139.

CHIN, J. T. 1965. J. Assn. Offic. Agri. Chem. 48:380. The auxiliary infrared equipment, micro beam condenser, discs, holders, etc., are available from Barnes Engineering Co., Stamford, Conn. 06902.

FLATH, R. A., N. HENDERSON, R. E. LUNDIN, AND R. TERANISHI. 1967. Applied Spectroscopy 21:17.

GOODLEY, P. C., AND M. GORDON. 1971. Isolation and characterization of industrial organic pollutants in water. Amer. Chem. Soc., Div. Water, Air, Waste Chem., Gen. Papers 11(1): 91–94.

————, AND ————. 1972a. Gas chromatographic analysis of halogenated quinoline compounds. J. Chromatog. Sci. 10:532.

————, AND ————. 1972b. Economical fluidized drier for gas chromatography packing material. Anal. Chem. 44:2415.

HARRIS, L. E., W. L. BUDDE, AND J. W. EICHELBERGER. 1974. Direct analysis of water samples. Anal. Chem. 46:1912.

HITES, R. A., AND K. BIEMANN. 1972. Amer. Chem. Soc., Div. Water, Air, Waste Chem., Gen. Papers 12(2):22.

KAHN, L., AND C. H. WAYMAN. 1964. Apparatus for continuous extraction of Nonpolar compounds from water applied to determination of chlorinated pesticides and intermediates. Anal. Chem. 36:1340.

KAWAHARA, F. K., J. W. EICHELBERGER, B. H. REID, AND H. STIERLI. 1967. Semi-automatic extraction of organic materials from water. J. Water Poll. Cont. Fed. 39:572.

KEITH, L. H. 1972. Amer. Chem. Soc., Div. Water, Air, Waste Chem., Gen. Papers 12(1): 113.

————, AND J. M. MCGUIRE. 1972. Computer controlled mass spectral characterizations of industrial organic pollutants. Amer. Chem. Soc., Div. Water, Air, Waste Chem., Gen. Papers 12(2):12.

KLEOPFER, R. D., AND B. J. FAIRLESS. 1972. Characterization of organic components in a municipal water supply. Environ. Sci. Technol. 6:1036.

WEBB, R. G., A. W. GARRISON, L. H. KEITH, AND J. M. MCGUIRE. 1973. Current Practice in GC-MS Analysis of Organics in Water. Southeast Research Laboratory, U. S. Environmental Protection Agency. EPA-R2-73-277.

Soluble Proteins of *Dieffenbachia*

Susamma Cherian and Walter T. Smith, Jr.
Department of Chemistry

and

Leonard P. Stoltz
Department of Horticulture, University of Kentucky, Lexington, Kentucky 40506

Abstract

The soluble proteins in the stalk of *Dieffenbachia picta* 'Rudolph Roehrs' were found to be separable into 3 fractions using a DEAE cellulose column; one of which comprised the major portion of the proteins. Separation of the soluble proteins using a Sephadex G-100 column indicated the presence of 3 major protein components with the molecular weights (1) above 150,000, (2) 4,400 ± 300, and (3) between 1,000 and 4,400. The electrophoretic patterns of the soluble proteins in the stalk of 5 different species and varieties of *Dieffenbachia* show differences among themselves in any particular time of the year and also exhibit distinctive changes corresponding to the season of the year. Toxicity of the stalk was mainly due to the water insoluble matter in the stalk, especially calcium oxalate.

Introduction

Many of the numerous species and varieties of *Dieffenbachia* or dumb cane are commonly found in homes and public places in spite of the fact that ingestion of the plant can cause severe corrosive burns of the mouth, oropharynx, and stomach. The toxic components in the plant have not been fully characterized. The toxicity has been attributed to calcium oxalate and some unidentified proteinaceous matter by Occhioni and Rizzini (1958) and to a glycoside by others (Locket 1965).

This paper deals with investigations on a few species and varieties of *Dieffenbachia* of commerce, with special emphasis on the soluble proteins in the stalk, their molecular weights, and electrophoretic patterns.

Experimental

Plant Materials

The species and varieties of the plant used for this study included: *Dieffenbachia amoena*, *aurantica*, *picta*, *picta* 'Arvida', and *picta* 'Rudolph Roehrs'. These were obtained from the greenhouse of the Horticulture Department of the University of Kentucky, Lexington, Kentucky.

Column Chromatography of Proteins

Separation of soluble proteins by column chromatography of the stalk of D. picta *'Rudolph Roehrs'.*—The stalk (20 g) was ground with 10 ml 0.1 M phosphate buffer, pH 7.0, filtered, and 10 ml of the solution was chromatographed. Apart from trial separations on Corning controlled pore glass (CPG-10) columns, the separation was carried out on a column 35 cm long (ID 2.5 cm) containing DEAE cellulose. The column was eluted with 0.1 M phosphate buffer, pH 7.0, and fractions (10 ml) collected every 15 min were monitored for absorptions at 260 and 280 nm. The concentration of proteins in each fraction was calculated using the empirical formula which includes the correction for the interference of nucleotides and nucleosides showing absorption at the same wavelengths as proteins (Colowick and Kaplan 1957).

Molecular weight determination of soluble proteins in the stalk of D. picta *'Rudolph Roehrs'.*—The stalk of the plant was ground well, the juice pressed out, and centrifuged. The centrifugate was diluted twice with 0.1 M NaCl solution and 0.5 ml of the diluted juice was chromatographed on a

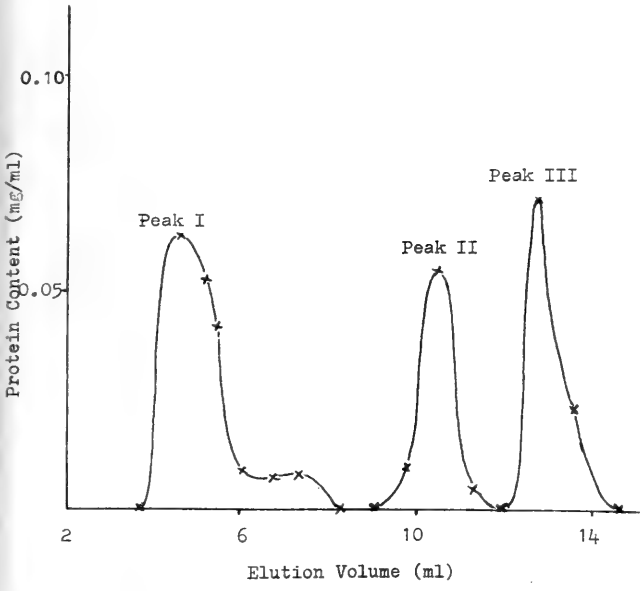

FIG. 1. Separation of soluble proteins in the stalk of *Dieffenbachia picta* 'Rudolph Roehrs' on Sephadex G-100 column.

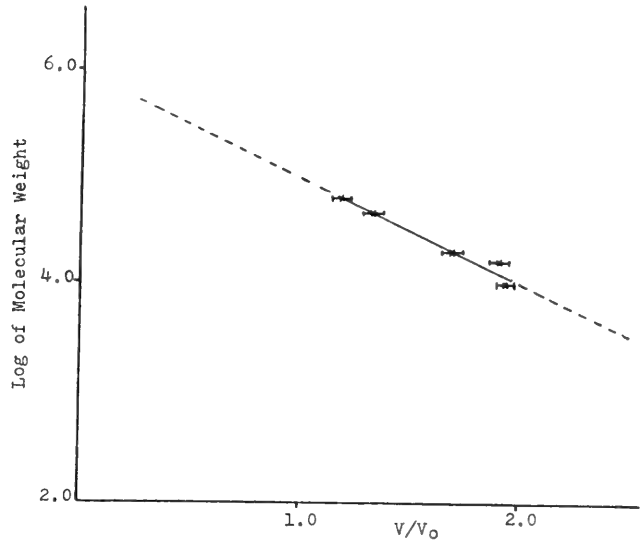

FIG. 2. Standard graph for molecular weight determination constructed using proteins of known molecular weight (see experimental part) on Sephadex G-100 column.

Sephadex column K9/30, 19 cm (G-100 and G-25). The column was eluted with 0.1 M NaCl solution at the rate of 0.2 ml/min. Fractions of 0.75 ml collected were monitored for UV absorption, and concentration of protein in them calculated. The column was calibrated with samples of known MW markers (e.g., cytochrome-c, myoglobin, chymotrypsinogen, ovalbumin, and albumin). The soluble proteins were separated into 3 main fractions, the molecular weights of which were determined by reference to a plot of the logarithm of molecular weight vs. the ratio of elution volume to the void volume of the column (V/Vo). The void volume, Vo, was determined using apoferritin which has a molecular weight higher than the upper fractionation limit of both Sephadex G-25 and G-100.

Electrophoresis of Soluble Proteins

Apart from some trials on juice pressed out from the leaves and petioles of the plant, most electrophoretic separations were carried out on the juice of the stalk of 5 species and varieties of *Dieffenbachia*. Electrophoresis was done in a Deluxe Electrophoresis Chamber (Gelman Instrument Company, Model No. 51170-1) using 2.5 × 30.5-cm cellulose polyacetate strips (Sepraphore III, Gelman Instrument Company) as support strips. The buffer used was 0.05 M Tris-Barbital sodium barbital buffer, pH 8.8 (Gelman High-Resolution Buffer). After electrophoresis the strips were stained by Ponceau S stain in 5 percent aqueous trichloracetic acid for 5–10 min and destained by successive washing in 5 percent acetic acid. The electrophoretic patterns were obtained in January, March, May, August, September, and November.

Paper Chromatography

Paper chromatography of amino acids and sugars was carried out on Whatman No. 1 and S & S 507 papers. For amino acids, the solvent used was prepared by mixing 500 ml freshly shaken mixture of equal volumes of *n*-butyl alcohol and water, with 60 ml glacial acetic acid. The upper butyl alcohol layer was used as the solvent, and 1 percent aqueous ninhydrin solution containing traces of pyridine was used as the spray reagent. For 2-dimensional chromatography of sugars, isopropyl alcohol: acetic acid:water (3:1:1) and phenol saturated with water (Clark 1964) were used as solvents. Ethyl acetate:acetic acid: water (3:1:3) (Parkinson 1954) was used

in uni-dimensional chromatography. The spray reagent was aniline acid oxalate.

Isolation of Calcium Oxalate

The stalk of *D. picta* 'Rudolph Roehrs' was blended with excess diethyl ether and the mixture filtered. The white material deposited on the top portion of the filter paper was separated, washed with diethyl ether, and dried. The starch in the powder was removed by successive suspension in boiling water and filtering until the iodine test on the filtrate was negative.

RESULTS AND DISCUSSION

Application of juice from various plant parts to the skin (forearm) of a test subject showed that the content of toxic component in the stalk of the 5 species and varieties of *Dieffenbachia* was considerably higher than that in the leaves and petioles. Separation of soluble proteins in the stalk of *D. picta* 'Rudolph Roehrs' on DEAE cellulose column showed 1 major protein fraction constituting most of the soluble proteins together with 2 minor fractions. But separation of the same on a Sephadex G-100 showed 3 major protein fractions as shown in Fig. 1. The molecular weights of the 3 fractions corresponding to peaks I, II, and III were above 150,000, 4,400 ± 300, and between 4,400 and 1,000, respectively. Peak I had an elution volume equal to the void volume of the Sephadex G-100 column used, showing that the molecular weight of this fraction was above 150,000, which is the upper fractionation limit for proteins on Sephadex G-100. Peak II corresponded to a molecular weight of 4,400 ± 300 as read from the calibration graph using the molecular weight markers. Peak III evidently had a molecular weight below 4,400. This fraction had an elution volume which corresponded to a molecular weight well inside the fractionation limit for proteins on the Sephadex G-25 tried. The fractionation limit for proteins on Sephadex G-25 columns is 5,000–1,000. Therefore, Peak III corresponded to a protein fraction with a molecular weight between 4,400 and 1,000.

Electrophoretic patterns of the proteins in the juice of the stalk of *D. amoena*, *D. picta*, *D. picta* 'Arvida', and *D. picta* 'Rudolph Roehrs' show differences among themselves in any particular time of the year. The seasonal variation pattern also differed in them. *D. aurantica* contained very little protein all through the year. Whatever protein it had did not migrate from the origin. Among the other species, *D. amoena* and *D. picta*, plants belonging to *D. picta* species showed more protein bands throughout the year. All the protein bands moved towards the cathode except for a band that appeared for *D. picta* 'Arvida' only in November, January, and March, which moved towards the anode. A maximum of 5 protein bands was observed in September and a minimum of 2 in January for *D. picta* 'Rudolph Roehrs'. The same trend was noticed for *D. picta* 'Arvida'. In September, the electrophoretic patterns of these 2 were very similar. *D. picta* showed 4 protein bands throughout the period under investigation except in September, when it had 5 clearly separated bands. *D. amoena* did not show any regular trends. It had a maximum of 5 protein bands in March, and 2 or 3 bands the rest of the year.

In addition to the electrophoretic pattern of proteins, the amino acid content of the juice of the stalk was also determined for 1 year for each of the 5 species and varieties. The amino acid content was very similar in all of them, and, moreover, the pattern did not show any significant change during this period. The maximum amino acid concentration occurred in September and was minimal in March and May. No attempts were made to identify the 6 or 7 different amino acids present.

Separation and identification of sugars in the juice pressed out from the stalk of *D. picta* 'Rudolph Roehrs' was attempted by 1- and 2-dimensional chromatography. This study showed that disaccharides were not present in detectable amounts in the juice. The juice contained glucose or galactose or both, and fructose or mannose or both, as shown by comparison with chro-

matograms of authentic samples. Fructose could be detected by Seliwanoff's test. The juice after hydrolysis with 2 M HCl did not show any additional spots.

Some observations were made regarding the toxicity of the plant. The stalk, when ground and placed on the skin, caused itching and swelling. The same effect was produced by petiole and leaf but to a much lesser extent. Centrifuged juice caused very little irritation to the skin but the residue after pressing out the juice did. So it appears that the toxicity is mostly due to insoluble matter in the stalk. Ground stalk extracted with 4 M HCl and washed thoroughly with water showed no toxic effect. Therefore, the toxic component might be calcium oxalate which is a skin irritant. The infrared spectrum of the white powder isolated from the stalk matched with that of calcium oxalate $\cdot H_2O$. The toxic characteristic of the stalk was, however, more intense than that of calcium oxalate itself. This could mean that the toxicity of the plant is likely to be a combined effect of calcium oxalate and some other unidentified constituent in the plant.

LITERATURE CITED

CLARK, M. J. 1964. Experimental Biochemistry. W. H. Freeman and Co., San Francisco, Cal. pp. 17–18.

COLOWICK, S. P., AND N. O. KAPLAN. 1957. Methods in Enzymology, Vol. III, Academic Press, Inc., New York, N. Y. pp. 451–452.

LOCKET, S. 1965. Clinical Toxicology. C. V. Mosby Co., St. Louis, Mo. pp. 430.

OCCHIONI, P., AND C. T. RIZZINI. 1958. Acao Toxica de Duas Sp. de *Dieffenbachia*. Rev. Brasil. Med., 15:10–16.

PARKINSON, T. L. 1954. Isolation of an Anthocyanin and Chlorogenic Acid from Canned Victoria Plums. J. Sci. Food Agr. 5:239–247.

Kentucky Algae. II[1]

GARY E. DILLARD, SHARON P. MOORE, AND LINDA S. GARRETT
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

This paper lists 176 species and varieties of algae previously unreported or infrequently reported as occurring in Kentucky. Included are first records for species of the genera *Spondylomorum*, *Eremosphaera*, *Tetrastrum*, *Tetragoniella*, *Phaeoplaca*, and *Cystodinium*.

INTRODUCTION

Reviews on the history of Kentucky phycological studies (Dillard and Crider 1970) and the known algal flora of the state (Dillard 1974) have appeared previously. As a contribution to a continuing effort to expand knowledge of the state's algal flora, the present report lists, in annotated form, 176 species and varieties of which 57 were previously unreported as occurring in Kentucky. Included are first records for the genera *Spondylomorum*, *Eremosphaera*, *Tetrastrum*, *Tetragoniella*, *Phaeoplaca*, and *Cystodinium*.

Collection Locales

All reports are based on at least monthly collections from Foster's Pond and Sloan's Crossing Pond, on the farm of C. L. Foster, Allen County, about 7 km from the damsite of Barren River Reservoir via county roads 252 and 1533 and in Mammoth Cave National Park, Edmonson County.

ANNOTATED CHECKLIST

Nomenclature follows that of Prescott (1962), West and West (1904–1912), and West et al. (1923). Entries preceded by a double asterisk represent new generic reports for the state; those preceded by a single asterisk represent new reports of lesser rank. Others represent taxa infrequently reported as occurring in Kentucky.

The annotations include reference to the time(s) of occurrence and principal subcommunity in which each taxon was collected. The freshwater subcommunities used are among those described by Round (1965), e.g., euplankton [P], neuston [N], epipelic [EP], epilithic [EL], epiphytic [ET], and epizooic [EZ]. Metaphyton [M] is used in the sense of Behre (1956) for those algae, commonly flagellates, chlorococcalean forms, desmids, and diatoms, which are neither euplanktonic nor attached. Rather, they are found intermingled with macroscopic algae and other aquatic plants.

CHLOROPHYCEAE

Volvocales

**Chlamydomonas patellaria* Whitford. Sloan's Crossing Pond; [M], November.

Phacotus lenticularis (Ehr.) Stein. Foster's Pond; [M], October–December.

Pandorina morum (Muell.) Bory. Foster and Sloan's Crossing ponds; [P], July–September.

Eudorina elegans Ehrenberg. Sloan's Crossing Pond; [P], April–June, September–October.

Volvox aureus Ehrenberg. Foster and Sloan's Crossing ponds; [P], March–May, October–January.

***Spondylomorum quaternarium* Ehrenberg. Sloan's Crossing Pond; [P], June–July.

Tetrasporales

Gloeocystis gigas (Kuetz.) Lagerheim. Sloan's Crossing Pond; [M], September–November.

Palmodictyon varium (Naeg.) Lemmermann. Foster's Pond; [M], January–April.

[1] Supported by a Faculty Research Grant, Western Kentucky University.

Tetraspora gelatinosa (Vauch.) Desvaux. Foster and Sloan's Crossing ponds; [ET,P], January–March.

Chaetophorales

**Stigeoclonium flagelliferum* Kuetzing. Foster's Pond; [ET], February–March.

**S. lubricum* (Dillw.) Kuetzing. Foster and Sloan's Crossing ponds; [ET,EP], January–February.

Draparnaldia acuta (Ag.) Kuetzing. Foster's Pond; [ET], November–March.

Aphanochaete repens Braun. Foster and Sloan's Crossing ponds; [ET], September–March.

**A. vermiculoides* Wolle. Sloan's Crossing Pond; [ET], October–November.

Coleochaete orbicularis Prinsheim. Foster and Sloan's Crossing ponds; [ET], September–November.

Cladophorales

**Basicladia chelonum* (Coll.) Hoffman et Tilden. Sloan's Crossing Pond; [EZ], June–July, common on turtle carapaces.

Oedogoniales

Oedogonium crassiusculum Wittrock. Foster's Pond; [ET], March–September, mature oospores present in April.

O. suecicum Wittrock. Foster's Pond; [ET], March–November, mature oospores present in March and April.

**Bulbochaete varians* Wittrock. Foster's Pond; [ET], April–December, mature oospores present in May.

Chlorococcales

**Characium rostratum* Reinhard. Foster's Pond; [ET], February–March.

Pediastrum boryanum (Turp.) Meneghini. Foster's Pond; [P,M], April–November.

P. duplex Meyen. Sloan's Crossing Pond; [P,M], June–September.

P. duplex var. *clathratum* (Braun) Lagerheim. Foster's Pond; [M], February–December.

P. duplex var. *cohaerens* Bohlin. Foster's Pond; [M,P], February–November.

P. tetras (Ehr.) Ralfs. Foster and Sloan's Crossing ponds; [P,M], May–December.

Sorastrum spinulosum Naegeli. Foster's Pond; [M], June–January.

Coelastrum cambricum Archer. Foster and Sloan's Crossing ponds; [P,M], April–November.

C. microporum Naegeli. Foster and Sloan's Crossing ponds; [M], April–November.

Botryococcus braunii Kuetzing. Foster and Sloan's Crossing ponds; [P], February–December.

Westella botryoides (West) de Wildemann. Foster's Pond; [P], May–December.

Dictyosphaerium ehrenbergianum Naegeli. Sloan's Crossing Pond; [P], March–September.

Planktosphaeria gelatinosa G. M. Smith. Foster and Sloan's Crossing ponds; [P], February–July.

***Eremosphaera viridis* DeBary. Sloan's Crossing Pond; [P], March–October.

Pachycladon umbrinus G. M. Smith. Foster's Pond; [P], June–September.

Oocystis elliptica West. Foster's Pond; [P], July–September.

O. parva West et West. Sloan's Crossing Pond; [P,M], May–October.

Ankistrodesmus falcatus (Corda) Ralfs. Sloan's Crossing Pond; [M], February–November.

A. falcatus var. *mirabilis* (West et West) G. S. West. Foster's Pond; [M], February–December.

A. spiralis (Turn.) Lemmermann. Foster's Pond; [M,P], March–December.

Closteriopsis longissima Lemmermann. Sloan's Crossing Pond; [P], April–December.

**C. longissima* var. *tropica* West et West. Foster's Pond; [P], May–December.

Selenastrum minutum (Naeg.) Collins. Foster's Pond; [P], November–December.

Kirchneriella lunaris (Kirchn.) Moebius. Sloan's Crossing Pond; [P,M], March–January.

Tetraedron caudatum (Corda) Hansgirg. Foster's Pond; [M], July–November.

T. minimum (Braun) Hansgirg. Foster's Pond; [M,P], November–December.

**T. muticum* (Braun) Hansgirg. Foster's Pond; [M], October–March.

T. planctonicum G. M. Smith. Foster and Sloan's Crossing ponds; [P], February–March.

T. regulare Kuetzing. Foster and Sloan's Crossing ponds; [P], June–October.

T. trigonum (Naeg.) Hansgirg var. *gracile* (Reinsch) DeToni. Foster's Pond; [P], July–October.

Scenedesmus abundans (Kirchn.) Chodat. Foster's Pond; [P], July–October.

S. arcuatus Lemmermann var. *platydisca* G. M. Smith. Foster's Pond; [M], September–December.

S. bijuga (Turp.) Lagerheim. Foster and Sloan's Crossing ponds; [M], July–February.

S. brasiliensis Bohlin. Foster's Pond; [P,M], June–March.

S. dimorphus (Turp.) Kuetzing. Foster's Pond; [P], October–December.

S. quadricauda (Turp.) Brebisson. Foster's Pond; [M,P], May–January.

***Tetrastrum heterocanthum* (Nordst.) Chodat. Foster's Pond; [M], July–September.

Crucigenia tetrapedia (Kirchn.) West et West. Foster's Pond; [M,P], June–September.

Zygnematales

**Spirogyra cleveana* Transeau. Foster's Pond; [M], February–April, mature zygospores present in March.

S. decimina (Muell.) Kuetzing. Foster's Pond; [M], January–May, mature zygospores present in May.

**S. suecica* Transeau. Foster's Pond; [M], February–June, mature zygospores present in April.

Netrium digitus (Ehr.) Itzigsohn et Rothe. Foster and Sloan's Crossing ponds; [M,P], January–December.

Penium margaritaceum (Ehr.) Brebisson. Foster and Sloan's Crossing ponds; [M], January–December.

Closterium gracile Brebisson. Sloan's Crossing Pond; [M], August–November.

C. intermedium Ralfs. Foster and Sloan's Crossing ponds; [P,M], January–December.

C. lunula Nitzsch. Foster's Pond; [M], January–December.

C. macilentum Brebisson. Foster's Pond; [P], March–January.

C. pritchardianum Archer. Foster's Pond; [P], May–March.

C. setaceum Ehrenberg. Sloan's Crossing Pond; [P], January–December.

C. turgidum Ehrenberg var. *giganteum* Nordstedt. Foster and Sloan's Crossing ponds; [P], January–December.

C. venus Kuetzing. Foster's Pond; [M], March–December.

Pleurotaenium trabecula (Ehr.) Naegeli. Foster and Sloan's Crossing ponds; [M], January–December.

**Euastrum abruptum* Nordstedt f. *minor* West et West. Sloan's Crossing Pond; [M], January–December.

E. ansatum Ralfs. Foster's Pond; [M,P], August–December.

E. binale (Turp.) Ehrenberg. Foster's Pond; [P], May–October.

E. elegans Brebisson. Sloan's Crossing Pond; [P], January–December.

**E. evolutum* (Nordst.) West et West var. *integrius* West et West. Sloan's Crossing Pond; [P,M], March–October.

E. pulchellum Brebisson. Foster's Pond; [P], April–January.

E. verrucosum Ehrenberg var. *alatum* Wolle. Foster's Pond; [M], March–December.

Micrasterias denticulata Brebisson. Sloan's Crossing Pond; [M], March–November.

**M. fimbriata* Ralfs. Sloan's Crossing Pond; [P], April–October.

M. laticeps Nordstedt. Sloan's Crossing Pond; [P,M], January–December.

M. pinnatifida (Kuetz.) Ralfs. Sloan's Crossing Pond; [M], June–November.

M. radiata Hassall. Foster and Sloan's Crossing ponds; [M,P], March–December.

**Cosmarium alpestre* Roy et Bissett. Foster's Pond; [M], August–October.

C. amoenum Ralfs. Sloans Crossing Pond; [M], January–December.

C. binum Nordstedt. Foster's Pond; [M], March–December.

**C. blyttii* Wille. Foster's Pond; [M], March–December.

C. circulare Reinsch. Foster and Sloan's Crossing ponds; [M,P], October–November.

**C. cyclicum* Lund. Sloan's Crossing Pond; [M], September–November.

**C. globosum* Bulnheim f. *minor* Boldt. Sloan's Crossing Pond; [P], August–December.

C. granatum Brebisson. Foster and Sloan's Crossing ponds; [P,M], March–January.

C. margaritatum (Lund.) Roy et Bissett. Sloan's Crossing Pond; [M], January–December.

C. ovale Ralfs. Foster and Sloan's Crossing ponds; [M], July–November.

C. portianum Archer. Foster's Pond; [P], March–December.

C. pyramidatum Brebisson. Sloan's Crossing Pond; [M], February–July.

C. regnellii Wille. Foster and Sloan's Crossing ponds; [P,M], February–October.

**C. trilobulatum* Reinsch. Foster and Sloan's Crossing ponds; [M], August–December.

C. turpinii Brebisson var. *eximium* West. Foster's Pond; [M], August–November.

**Xanthidium cristatum* Brebisson var. *leiodermum* West et West. Sloan's Crossing Pond; [M], January–December.

Staurastrum alternans Brebisson. Foster's Pond; [P], January–December.

**S. crytocerum* Brebisson. Sloan's Crossing Pond; [M], February–May.

S. cuspidatum Brebisson. Foster's Pond; [P], April–January.

S. gladiosum Turner. Foster's Pond; [P], August–November.

**S. lunatum* Ralfs. Sloan's Crossing Pond; [P], January–December.

**S. margaritaceum* (Ehr.) Meneghini. Foster's Pond; [P], August–March.

**S. minnesotense* Wolle. Sloan's Crossing Pond; [P], August–October.

**S. orbiculare* Ralfs. Foster's Pond; [P], January–December.

S. paradoxum Meyen var. *parvum* West. Foster's Pond; [P], March–January.

S. setigerum Cleve. Sloan's Crossing Pond; [P], January–December.

Arthrodesmus incus (Breb.) Hassall var. *extensus* Andersson. Sloan's Crossing Pond; [M], January–December.

A. octocornis Ehrenberg. Sloan's Crossing Pond; [M], March–November.

Desmidium aptogonum Brebisson. Foster and Sloan's Crossing ponds; [M], February–November.

Hyalotheca dissiliens (Smith) Brebisson. Sloan's Crossing Pond; [M], January–December.

H. mucosa (Mert.) Ralfs. Sloan's Crossing Pond; [M], March–November.

**Bambusina brebissonii* Kuetzing. Sloan's Crossing Pond; [M], April–November.

EUGLENOPHYCEAE

Euglenales

Euglena acus Ehrenberg. Foster's Pond; [P], July–September.

E. ehrenbergii Klebs. Foster's Pond; [M], September–October.

**E. elastica* Prescott. Foster's Pond; [M], July–August.

E. fusca (Klebs) Lemmermann. Foster's Pond; [M], July–October.

**E. helicoideus* (Bern.) Lemmermann. Foster's Pond; [P], October–January.

**E. oxyuris* Schmarda var. *minor* Prescott. Foster's Pond; [M], March–December.

E. polymorpha Dangeard. Foster's Pond; [P], December–April.

**E. proxima* Dangeard. Sloan's Crossing Pond; [M], January–December.

E. spirogyra Ehrenberg. Sloan's Crossing Pond; [P], July–November.

E. spiroides Lemmermann. Sloan's Crossing Pond; [M], June–November.

E. tripteris (Duj.) Klebs. Foster's Pond; [M], June–October.

**Lepocinclis acuta* Prescott. Sloan's Crossing Pond; [P,M], May–October.

L. ovum (Ehr.) Lemmermann. Foster's Pond; [M], July–November.

Phacus anacoelus Stokes. Sloan's Crossing Pond; [P,M], July–October.

**P. brevicaudata* (Klebs) Lemmermann. Sloan's Crossing Pond; [M], June–September.

**P. helikoides* Pochmann. Foster and Sloan's Crossing ponds; [P], July–November.

P. longicauda (Ehr.) Dujardin. Foster and Sloan's Crossing ponds; [P,M], September–January.

P. orbicularis Huebner. Sloan's Crossing Pond; [P], July–January.

P. pleuronectes (Muell.) Dujardin. Foster and Sloan's Crossing ponds; [P,M], March–December.

**P. pseudoswirenkoi* Prescott. Sloan's Crossing Pond; [P], August–January.

**P. segretii* Allorge et Lefevre var. *ovum* Prescott. Sloan's Crossing Pond; [P], December–January.

**P. suecicus* Lemmermann. Sloan's Crossing Pond; [P], June–November.

**Trachelomonas allia* Drezepolski. Foster's Pond; [P], August–January.

**T. bernardinensis* Vischer. Foster's Pond; [P], May–August.

**T. cylindrica* Ehrenberg. Foster's Pond; [P], September–March.

**T. ensifera* Daday. Sloan's Crossing Pond; [P], June–October.

T. hispida (Perty) Stein. Foster's Pond; [P], January–December.

**T. playfairii* Deflandre. Sloan's Crossing Pond; [P,M], August–October.

T. robusta Swirenko. Sloan's Crossing Pond; [M,P], January–December.

**T. rugulosa* (Stein) Deflandre. Foster's Pond; [M], September–December.

T. similis Stokes. Foster's Pond; [M,P], May–July.

**T. superba* (Swir.) Deflandre var. *spinosa* Prescott. Foster's Pond; [P,M], October–March.

T. volvocina Ehrenberg. Foster and Sloan's Crossing ponds; [P,M], January–December.

XANTHOPHYCEAE

Heterococcales

***Tetragoniella gigas* Pascher. Sloan's Crossing Pond; [M], August–November.

Ophiocytium capitatum Wolle. Foster's Pond; [M], August–November.

O. parvulum (Perty) Braun. Foster and Sloan's Crossing ponds; January.

Heterotrichales

Tribonema minus (Wille) Hazen. Foster's Pond; [M], September–December.

CHRYSOPHYCEAE

Phaeoplacales

****Phaeoplaca thallosa** Chodat. Sloan's Crossing Pond; [EL], September–March.

Chrysomonadales

***Mallomonas acaroides** Perty. Sloan's Crossing Pond; [P,M], November–March.

M. caudata Iwanoff. Foster's Pond; [P], September–February.

***Synura sphagnicola** Korschikov. Sloan's Crossing Pond; [P], September–January.

S. uvella Ehrenberg. Foster and Sloan's Crossing ponds; [P], January–December.

Dinobryon sertularia Ehrenberg. Foster and Sloan's Crossing ponds; [P], February–September.

Uroglena volvox Ehrenberg. Sloan's Crossing Pond; [P], March–May, October–January.

Isochrysidales

Rhipidodendron splendidum Stein. Foster and Sloan's Crossing ponds; [M], August–March.

DINOPHYCEAE

Gymnodiniales

***Gymnodinium fuscum** (Ehr.) Stein. Sloan's Crossing Pond; [P,M], January–December.

***G. palustre** Schilling. Sloan's Crossing Pond; [P,M], January–December.

Peridiniales

Peridinium cinctum (Muell.) Ehrenberg. Foster's Pond; [P,M], July–September.

***P. willei** Huitfeld-Kaas. Sloan's Crossing Pond; [P], October–April.

***P. wisconsinense** Eddy. Sloan's Crossing Pond; [P,M], January–December.

Ceratium hirundinella (Muell.) Dujardin. Foster and Sloan's Crossing ponds; [P], April–November.

Dinococcales

****Cystodinium iners** Geitler. Sloan's Crossing Pond; [M], April–November.

CRYPTOPHYCEAE

Cryptomonadales

Cryptomonas erosa Ehrenberg. Foster and Sloan's Crossing ponds; [P], October–January.

C. ovata Ehrenberg. Foster's Pond; [P], October–January.

CYANOPHYCEAE

Chroococcales

Coccochloris peniocystis (Kuetz.) Drouet et Daily. Foster's Pond; [P], January–December.

Agmenellum quadruplicatum Brebisson. Foster's Pond; [M,P], March–October.

Anacystis cyanea (Kuetz.) Drouet et Daily. Foster's Pond; [M], January–December.

Oscillatoriales

***Spirulina subsalsa** Oersted. Foster's Pond; [M], July–November.

Oscillatoria princeps Vaucher. Foster's Pond; [M], January–December.

O. splendida Greville. Foster's Pond; [M], August–November.

***Schizothrix calcicola** (Ag.) Gomont. Foster's Pond; [M], February–April.

LITERATURE CITED

BEHRE, K. 1956. Die Algen besiedlund einiger Seen um Bremen und Bremerhaven. Ver. Inst. Meersk. Bremerhaven, Ger. 4:221–283.

DILLARD, G. 1974. An Annotated Catalog of Kentucky Algae. Ogden College, Western Kentucky University, Bowling Green, Ky. 135 pp.

DILLARD, G., AND S. CRIDER. 1970. Kentucky algae, I. Trans. Ky. Acad. Sci. 31:66–72.

PRESCOTT, G. 1962. Algae of the Western Great Lakes Area. Wm. C. Brown Co., Dubuque, Iowa. 977 pp.

ROUND, F. 1965. The Biology of Algae. E. Arnold, Ltd., London, England. 269 pp.

WEST, W., AND G. S. WEST. 1904–1912. A Monograph of the British Desmidiaceae. The Ray Society, London, England. Vols. I–IV.

——, ——, AND N. CARTER. 1923. A Monograph of the British Desmidiaceae. The Ray Society, London, England. Vol. V.

Distribution, including New State Records, of Fishflies in Kentucky (Megaloptera: Corydalidae)

DONALD C. TARTER, WILLIAM D. WATKINS,[1] AND MICHAEL L. LITTLE
Department of Biological Sciences, Marshall University, Huntington, West Virginia 25701

ABSTRACT

The fishflies *Chauliodes pectinicornis* and *Nigronia serricornis* are reported for the first time for Kentucky. Also, new county records are noted for *C. rastricornis*, *N. fasciatus*, and *Neohermes concolor*. Emergence data are presented for *N. concolor*.

INTRODUCTION

Several investigators, including Tarter et al. (1975), Watkins et al. (1975), Tarter and Watkins (1974), Peterson (1974, unpublished doctoral dissertation, Michigan State University, East Lansing, Michigan), Evans (1972, unpublished doctoral dissertation, Oregon State University, Corvallis, Oregon), Neunzig (1966), Cuyler (1965), and Davis (1903), have reported distributional, ecological, and taxonomical information of fishflies in North America.

Three eastern genera of fishflies, *Chauliodes*, *Neohermes*, and *Nigronia*, are in the subfamily Chauliodinae. Usually, the larvae of *Nigronia fasciatus* and *N. serricornis* are found under rocks in streams, whereas the larvae of *Chauliodes pectinicornis* and *C. rastricornis* are confined to logs in ponds and marshes. The larva of *Neohermes concolor* is unknown.

Hazard (1960, unpublished master's thesis, Ohio State University, Columbus, Ohio) in a revision of the genera *Chauliodes* and *Nigronia* in the Eastern United States, reported 1 record of *N. fasciatus* (Bluegrass Region) and 1 record of *C. rastricornis* (Pennyroyal Region) for Kentucky. Minshall (1968), in studying the community dynamics of the benthic fauna in a woodland springbrook, recorded *N. fasciatus* from Morgan's Creek, Meade County, Kentucky. One adult of *Neohermes concolor* was collected from Mammoth Cave National Park, Edmonson County, Kentucky (Flint 1965). The primary objective of this paper was to report new state and county distributional records of fishflies for Kentucky.

[1] Present Address: Ashland Oil Incorporation, Research and Development Department, Catlettsburg, Kentucky 41129

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We express our appreciation to the following people who loaned specimens: Dr. Donald Batch, Eastern Kentucky University (EKU); Mr. Larry Canterbury and Dr. Charles Covell, University of Louisville (UL); Dr. Gerald DeMoss, Morehead State University (MSU); Mr. Larry Evans, United States Army Corps of Engineers (USACE); Dr. Oliver Flint, Jr., United States National Museum (USNM); Dr. Paul Freytag, University of Kentucky (UK); Dr. J. E. H. Martin, Biosystematics Research Institute (BRI); and Dr. Charles A. Triplehorn, Ohio State University (OSU).

NEW STATE RECORDS

Chauliodes pectinicornis is reported for the first time for Kentucky. It was collected from the Appalachian Plateau and the Bluegrass Region (Fig. 1).

Boyd Co., Ashland Oil Refinery, 13 June and 29 August (1♂, 1♀; Watkins); Jefferson Co. (Covell, UL); Rowan Co. (Whiters, MSU).

Nigronia serricornis is recorded for the first time for Kentucky. The records are primarily for 5 counties in the Bluegrass Region (Fig. 1). However, a few records are from the Appalachian Plateau and the Pennyroyal Region.

Bullitt Co., Wilson Ck. (Canterbury,

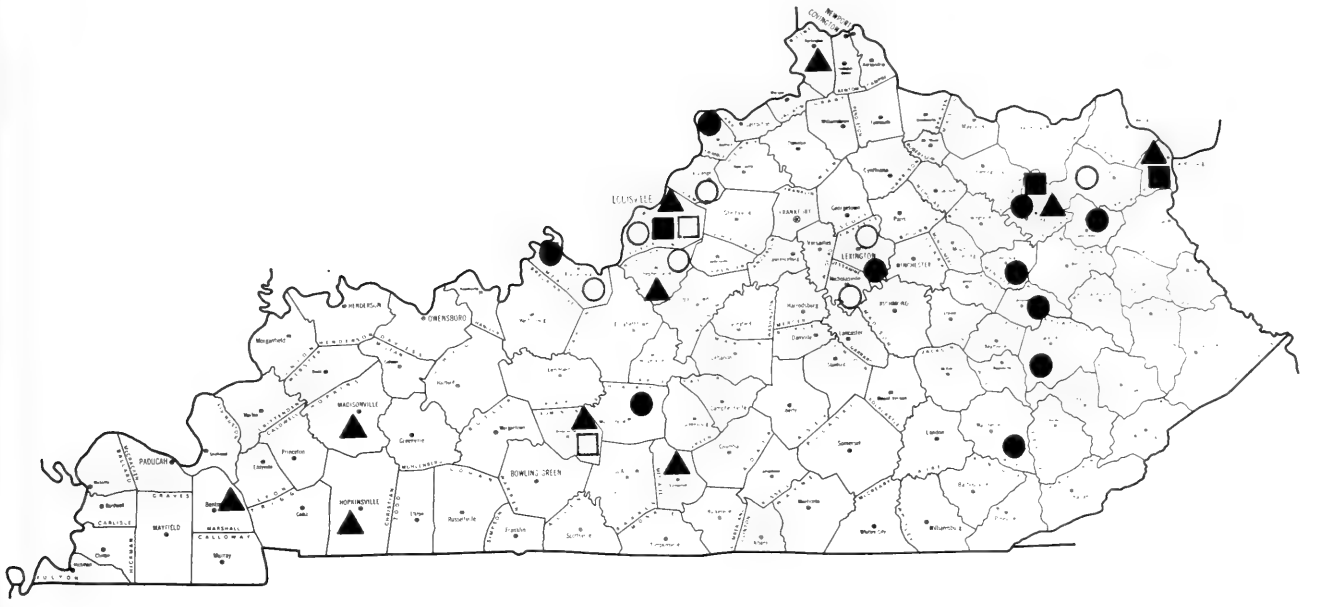

FIG. 1. Distribution of *Neohermes concolor* (triangle), *Nigronia fasciatus* (closed circle), *N. serricornis* (open circle), *Chauliodes pectinicornis* (closed square), and *C. rastricornis* (open square), within Kentucky.

UL); Carter Co., Tygarts Ck. (Evans, USACE); Fayette Co., Boone Ck. (Freytag, UK); Jefferson Co. (Page and Roberts, UL); Jessamine Co., Indian Falls (Freytag, UK); Meade Co., Doe Run (Rhines, UL); Oldham Co. (UL); Rockcastle Co., 23 May and 1 June (2♀♀; BRI).

NEW COUNTY RECORDS

One new record was found for *Chauliodes rastricornis.* Jefferson Co., Caperton Swamp (Canterbury, UL) (Fig. 1).

New records for *Nigronia fasciatus* are primarily from the Appalachian Plateau (6 counties) (Fig. 1). Also, records are available from Fayette and Trimble counties in the Bluegrass Region and Hart and Meade counties in the Pennyroyal Region.

Breathitt Co., Little Millseat Br. (Freytag, UK); Clay Co., Big Ck. (Early, UL); Elliott Co., Little Sandy River (Evans, USACE); Fayette Co., Tates Ck. (Freytag, UK); Hart Co., Bacon Ck. (Steele, UL); Menifee Co., Clifty Ck. (Freytag, UK) and Beaver Ck. (Hamlin, MSU); Rowan Co. (Blair, MSU); Trimble Co., Corn Ck. (Steele, UL); Wolfe Co., Swift Camp Ck. (Freytag and Young, UK) and Tight Hollow Ck., Mill Ck. (Batch, EKU).

Neohermes concolor is the most widely distributed fishfly in Kentucky (Fig. 1). Adults are mainly from the Bluegrass and Pennyroyal regions. In addition, the fishfly occurs in the Appalachian Plateau, Western Coal Field, and East Gulf Coastal Plain.

Boone Co., Big Bone Lick Park, 29 June (6♀♀, 1♂; Freytag and Leppert, UK); Boyd Co., Ashland Oil Refinery, 12 June–16 July (44♀♀, 7♂♂; Watkins); Bullitt Co., Bernheim Forest, 18 June (1♀, 1♂; Canterbury, UL); Christian Co., 14 June (3♂♂; Moore, OSU); Hopkins Co., 25 May (1 adult; Scheibner, UK); Jefferson Co., Waverly Park, 15 June (1♀, 1♂; Brownell, UL); Marshall Co., Kenlake State Park, 22–23 June (2♀♀, 2♂♂; Freytag, UK); Metcalfe Co., 21 June (1♀; Park, UL); Rowan Co., 27 June (1♀; BRI).

Based on adult collections (55♀♀, 15 ♂♂) throughout Kentucky, emergence of *N. concolor* extended from 25 May to 16 July. In Boyd County, 13 collections of adults indicated that peak emergence occurred on 3 July (emergence period, 12 June–16 July).

LITERATURE CITED

CUYLER, R. D. 1965. The larvae of *Nigronia fasciatus* Walker (Megaloptera: Corydalidae). Entomol. News 76:192–195.

DAVIS, K. C. 1903. Sialididae of North and South America. *In* Aquatic insects in New York. N. Y. St. Mus. Bull. 68:442–487.

FLINT, JR., O. S. 1965. The genus *Neohermes* (Megaloptera: Corydalidae). Psyche 72: 255–263.

MINSHALL, G. W. 1968. Community dynamics of the benthic fauna in a woodland springbrook. Hydrobiologia 32:305–339.

NEUNZIG, H. H. 1966. Larvae of the genus *Nigronia* Banks (Neuroptera: Corydalidae). Proc. Entomol. Soc. Wash. 68:11–16.

TARTER, D. C., AND W. D. WATKINS. 1974. Distribution of the fishfly genera *Chauliodes* Latreille and *Nigronia* Banks in West Virginia (Megaloptera: Corydalidae). Proc. W. Va. Acad. Sci. 46:146–150.

————, W. D. WATKINS, AND M. L. LITTLE. 1975. Life history of the fishfly, *Nigronia fasciatus* (Megaloptera: Corydalidae). Psyche 82:81–88.

WATKINS, W. D., D. C. TARTER, M. L. LITTLE, AND S. D. HOPKINS. 1975. New records of fishflies for West Virginia (Megaloptera: Corydalidae). Proc. W. Va. Acad. Sci. 47: In press.

A Preliminary Study of a Virgin Forest Tract of the Cumberland Plateau In Laurel County, Kentucky

Joe E. Winstead and Kenneth A. Nicely
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

A deep gorge forest community, proposed as the Rock Creek Natural Area, is dominated by hemlock, tulip poplar, sweet birch, and red maple with a high density of trees and large basal area per hectare. It is a unique area that shows great potential for more detailed analysis of the structure and function of the mixed mesophytic forests of Kentucky.

Introduction

Although the literature is voluminous concerning forest structure in the eastern United States, there are very few studies involving undisturbed, virgin, or relict forest tracts in Kentucky, and the existence of mature forest stands that have not been subject to man's impact are rare indeed in the state. In order to add to information concerning what represents perhaps one of the few deep ravine forest communities of the Cumberland Plateau still in its primeval condition, and to initiate further investigations of the area, this study was undertaken in 1973–1974.

The site is in the Sawyer Quadrangle, U.S. Geological Survey Topographic Quadrangle Series (36° 59′ N. Lat., 84° 17′ W. Long.) and lies 30.6 km southwest of London in southwestern Laurel County, Kentucky (Fig. 1). The study area is designated as the Rock Creek Gorge which lies within the boundary of land proposed as the Rock Creek Natural Area (72.47 ha) by the U.S. Forest Service (Hemmingway 1938). That designation was made in 1939, and as such it has been preserved in unmodified condition with no timber removal and no agricultural use, and is within the boundaries of the Daniel Boone National Forest.

The Rock Creek Gorge extends from almost a sheer cliff line to a depth of approximately 48 m and covers an area from the Rockcastle River to the head of the gorge of about 2 km. The gorge is narrow and from rim to rim is perhaps 460 m. The natural beauty of the gorge and adjacent cliffs is striking. The sandstone cliffs dropping straight down or more often with "rock house recesses" to dense rhododendron stands, numerous small waterfalls from the cliff rim, and the immense trees, which often tower above the cliff line give this site a primeval appearance. The rugged topography makes it one of the most appealing places to visit within the Cumberland Plateau and perhaps in the eastern states. There are at best only a few such sites with these particular combinations of qualities remaining in the Appalachian Region.

This area lies within the Mixed Mesophytic Forest Region, Cliff Section, as described by Braun (1950) and was used by Braun as an example of gorge vegetation in hemlock mixed mesophytic forests. The location probably is representative of the original vegetation of this physiographic region. This site was included under the broad theme study of *Mixed Mesophytic, Western Mesophytic, and Oak–Chestnut Regions of the Eastern Deciduous Forest* by Catherine Keever for the National Park Service, Department of Interior, and was subject to evaluation by the National Park Service as a potential Natural Landmark. Such an evaluation was made by the authors for the National Park Service in 1973 and that work initiated the present investigation.

Acknowledgments

Special thanks are due Blaine Ferrel, Michael Held, Sharon Moore, William

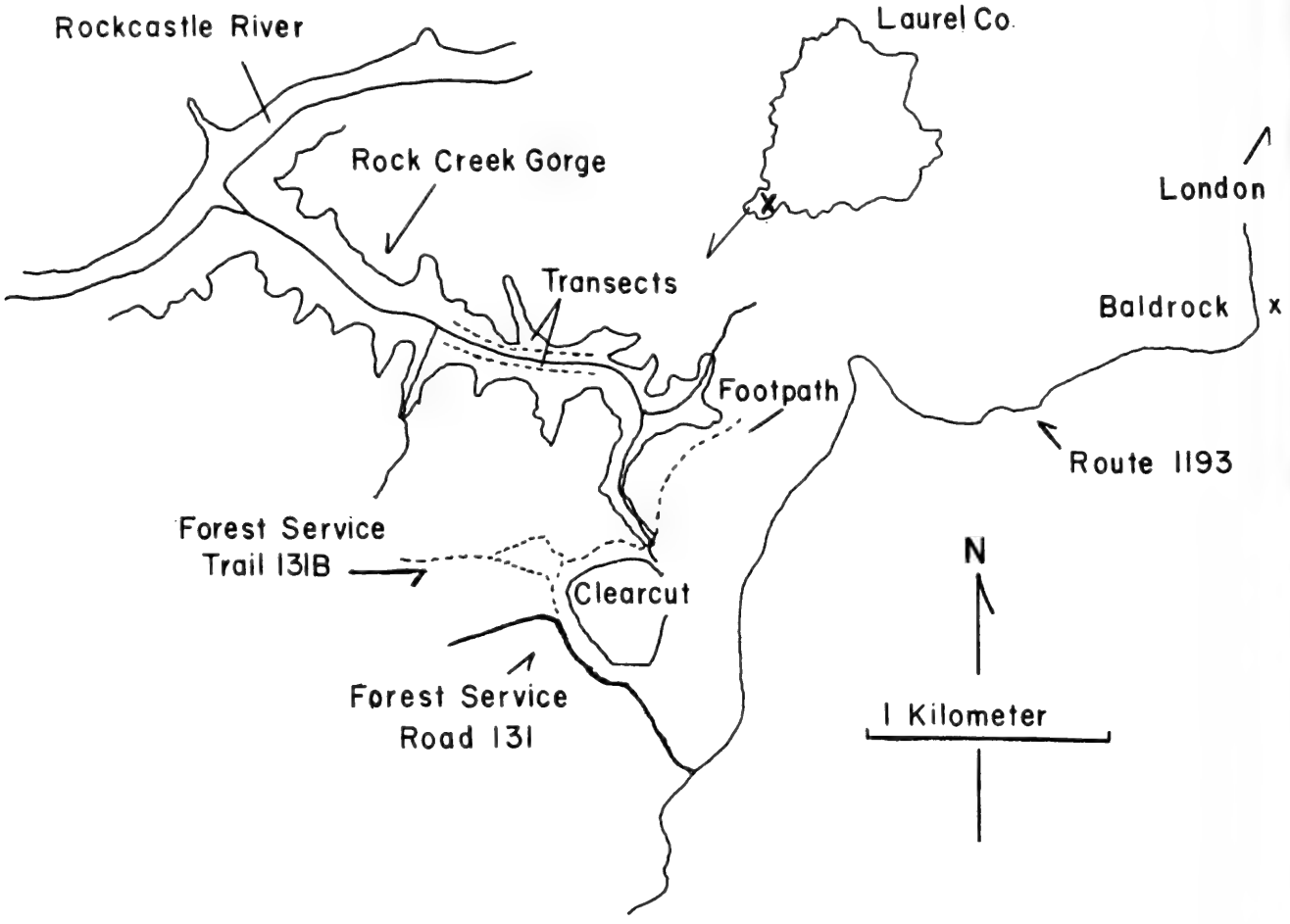

FIG. 1. Location of Rock Creek Gorge in Laurel County, Kentucky

Randel, Robert Van Hoff, Judy Van Hoff, and Linda Walker who aided in the data collection. We are also indebted to the personnel at the headquarters of the Daniel Boone National Forest in Winchester, Kentucky, and the staff at the District Forest Ranger's Office in London, Kentucky, for their cooperation.

METHODS

In the upper section of the gorge, 2 750-m transects were arbitrarily placed approximately halfway between the stream and cliff line with one transect on either side of the stream (Fig. 1). Each transect ran in a northwesterly direction on a compass line of about 320 deg. Along each transect, trees greater than 10.16 cm (4 in) in diameter breast high (dbh) were sampled using the random pairs method of Cottam and Curtis (1949, 1950). The random pairs were determined at 30-m intervals along each transect line. A total of 50 pairs was sampled. The presence of numerous large trees was striking throughout the area and an additional 10 of the largest seen but not sampled in the random pairs method were also measured for diameter. One large hemlock was cored for growth ring analysis.

RESULTS

The analysis revealed 13 different species composing the tree flora with 4 species (hemlock, tulip poplar, sweet birch, and red maple) composing over 82 percent of the basal area measured and making up 64 percent of the total (Table 1). The average distance between trees sampled was 5.0 m with a range of 2.4 to 10.6 m. The average dbh of the 100 trees measured was 28.1 cm (11.1 in). Calculation of the mean area per individual (16.0 m^2) indicated that the area of the gorge sampled contains some 672.8 trees per hectare (272.4/acre). Using the average diameter value, the es-

TABLE 1.—THE NUMBER (N), BASAL AREA IN SQUARE METERS (BA), PERCENTAGE OF TOTAL BASAL AREA (%BA), AND AVERAGE DIAMETER BREAST HIGH IN CENTIMETERS (ADBH) OF TREES OVER 10 CM DIAMETER SAMPLED IN THE ROCK CREEK GORGE

	N	BA	%BA	ADBH
Tsuga canadensis	23	4.37	44.5	39.0
Liriodendron tulipifera	13	1.86	19.8	37.6
Betula lenta	14	.95	10.1	25.4
Acer rubrum	14	.75	8.0	24.6
Quercus rubra	5	.47	5.0	30.5
Ilex opaca	9	.30	3.2	19.1
Nyssa sylvatica	6	.27	2.8	21.2
Prunus serotina	5	.19	1.9	20.6
Fagus grandifolia	5	.08	.9	14.2
Quercus alba	1	.07	.8	30.5
Magnolia macrophylla	2	.04	.4	14.7
Carpinus caroliniana	1	.03	.3	19.1
Cornus florida	2	.02	.2	10.2

timated number of trees per hectare gives a calculated basal area of 47.5 m^2/ha.

The 10 measurements of very large trees noted outside the sampling area averaged 91.2 cm (35.9 in). Of the trees, 5 were hemlocks with diameters of 57.1, 74.9, 82.5, 91.7, and 100.1 cm, 4 tulip poplars measured 90.2, 103.1, 106.2, 113.0 cm dbh, and 1 red maple showed a dbh of 91.2 cm. The hemlock with a diameter of 57.1 cm was cored and 225 growth rings counted.

DISCUSSION

This brief analysis confirms in part an earlier cursory investigation by Braun (1950) and also indicates the need for much more detailed studies concerning the structure and functions of Kentucky's mixed mesophytic forest sites. The sampling of 117 canopy trees by Braun (1950) included 12 different species compared with the 13 tree species of the present study. The earlier work indicated hemlock, tulip poplar, and red maple as dominant species which coincides with this study except the 1974 analysis also shows sweet birch being equally as dominant as red maple. Braun's canopy study indicated sweet birch composing 6.8 percent of the total trees noted. The present study included 9 of the 12 different species listed by Braun. The random pairs analysis did not detect a trace of *Quercus montana*, *Oxydendron arboreum*, and *Castenea dentata* as recorded by the early survey by Braun. The removal of *Castanea dentata* from the area by the chestnut blight of the 1930's might have been an event that lead to the increase in sweet birch. Species included in the 1974 study that were not noted by Braun were *Prunus serotina*, *Quercus alba*, *Carpinus caroliniana*, and *Cornus florida*. The 5 percentage species composition of black cherry found in 1974 might also be the result of changes due to the elimination of the chestnut. The close similarity of the dominant tree species with data collected by Braun some 40 years earlier indicates the stability of this deep ravine woods of the mixed mesophytic forest.

Little quantitative data are available concerning undisturbed forest sites in Kentucky. Secondary succession studies in a hemlock–mixed mesophytic forest known as "Tight Holler" in Wolfe County have been recently published by Herman and See (1973). Although the "Tight Holler" site is referred to as virgin tract, there is evidence of considerable disturbance over much of the area by logging, and extensive agricultural activity along the immediate boundaries of the location also indicate dangers to its preservation. As a natural study area of an undisturbed forested area, the authors feel that the Rock Creek Gorge surpasses the better known Wolfe County location.

The Rock Creek Gorge probably compares favorably with sections of the Lilley Cornett Woods in Letcher County, Kentucky. Significant data on the composition of Lilley Cornett Woods have been compiled by Martin and Shepherd (1973), and Martin (1975). The hemlock communities of northeastern slopes in Lilley Cornett Woods show less density (321 stems/ha compared to 672 stems/ha) and basal area (42.4 m^2/ha compared to 47.5 m^2/ha) than the Rock Creek site. The existence of these 2 outstanding virgin forest tracts

and their protection from any commercial disturbance by man provides great potential for more in-depth studies comparing forest structure and function of the Cumberland Plateau.

Although no quantitative data have been gathered, the area above and adjacent to the cliff rim of the Rock Creek Gorge is worthy of mention. Second growth oak–hickory forest communities or in some instances oak–tulip tree and oak–pine or pine stands characterize the surrounding terrain. Common constituents are *Quercus alba*, *Q. velutina*, *Q. stellata*, *Carya ovata*, *C. tomentosa*, *Cornus florida*, and *Pinus echinata*. One would expect to find other oaks and hickories along with sourgum, red maple, and Virginia pine. These forests lie in interstream areas and have a somewhat xeric aspect in sharp contrast to the true mixed mesophytes in the gorge proper. Shrubs number only a few species but often form scattered and even dense patches. Species of *Vaccinium* and other heath type shrubs prevail. The most significant of these are the abundant patches of the box huckleberry *Gaylussacia brachycera*. This shrub is common, and occurs in similar habitats in Laurel and McCreary counties but is relatively rare as only 12 or so locations are recorded throughout the eastern United States. This in itself makes the general area somewhat unique. Along the small streams which dissect these forest communities and then drop suddenly into the gorge below, more mesic tree species and some secondary hemlock are present.

The area immediately surrounding the south side of the gorge has been designated a research area by the U.S. Forest Service. There is one clear-cut area that was established in 1965. This 10-year-old clear-cut section with excellent second growth mesic forest on the bluffs and ridges along with the primeval hemlock–hardwood association of the gorge gives this site a unique significance in regard to educational values. This site lends itself as a valuable demonstration of old, intermediate, and young growth stages of the Mixed Mesophytic Forest Region. The integrity of the Rock Creek drainage area is assured by the designation of the site as a research and natural area by the U.S. Forest Service and by the selection of the area as a registered natural landmark by the Department of the Interior.

LITERATURE CITED

BRAUN, E. L. 1950. Deciduous forests of eastern North America. Hafner Publ. Co., New York, N. Y. 596 pp.

COTTAM, G., AND J. T. CURTIS. 1949. A method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology 30:101–104.

————, AND ————. 1955. Correction for various exclusion angles in the random pairs method. Ecology 36:767.

HEMMINGWAY, R. T. 1938. Report on Rock Creek Natural Area, Cumberland National Forest, Laurel County, Kentucky. Report filed at the U.S. Forest Service Office, Winchester, Kentucky. 9 pp.

HERMAN, T., AND M. G. SEE. 1973. Secondary succession following fire in "Tight Holler," Kentucky. Castanea 38:327–285.

MARTIN, W. H. 1975. The Lilley Cornett Woods—a stable mixed mesophytic forest in Kentucky. Bot. Gaz. 136:171–183.

————, AND C. SHEPHERD. 1973. Trees and shrubs of Lilley Cornett Woods, Letcher County, Kentucky. Castanea 38:327–335.

Distribution and Habitat Preference of *Etheostoma histrio* in Kentucky

Morgan E. Sisk and David H. Webb
Hunter Hancock Biological Station, Department of Biological Sciences,
Murray State University, Murray, Kentucky 42071

Abstract

Etheostoma histrio has been taken from 5 locations in Kentucky, all within coastal plain streams. The species preferred deep riffle–detritus habitats in 3 of those streams and may soon be extirpated from those waters.

Introduction

A recent paper by Tsai (1968) discussed the distribution and habitat of the harlequin darter *Etheostoma histrio* throughout its range. Subsequent comments by Hubbs and Pigg (1972) indicated a difference in the habitat preference of Texas and Oklahoma populations of the species when compared with those east of the Mississippi River, as mentioned by Tsai (1968). Herewith, we submit additional information on habitat preference and distribution of the species based on collections from Kentucky.

Results

The first collection of *E. histrio* from Kentucky was reported by Woolman (1892) who took 2 specimens from "Rough Creek" (= Rough River) near Hartford, Kentucky. The validity of this record is questionable since no other extant specimens exist from Rough River and recent attempts at collecting the species from the stream have failed. In 1954, Dr. William Clay (pers. comm.) collected 2 specimens from Blood River, near Murray, Kentucky. More recently, *E. histrio* has been taken from Obion Creek (Smith and Sisk 1969), Bayou de Chien (Webb and Sisk 1975), and Mayfield Creek (Sisk, unpublished). These 3 streams are tributaries to the Mississippi River and present 2 distinct habitat types, upland portions whose bottom materials are mostly sand and gravel, and lowland areas where detritus, muck, logs, and sticks overlie sandy and/or clay bottoms.

We have collected *E. histrio* from both habitats, but upland areas produced only an occasional single specimen from beneath undercut banks choked with fine, matted roots where strong currents prevailed. All but 4 of our collections of the species were from lowland stream courses where log jams had created strong midstream riffles. Within these obstructions, decaying leaves, silt, and brush had collected forming the detritus microhabitat described by Hubbs and Pigg (1972) from which they collected the species in Texas and Oklahoma. On one occasion, we found 17 specimens in 2 such riffles about 90 m apart. Pflieger (1971) referred to a similar habitat for *E. histrio* in Missouri but from quiet water. Smith (1968) reported that the Embarras River population in Illinois was found in deep sand-bottomed riffles containing logs or stumps. The species was found inhabiting riffles created by rocks, gravel, or vegetational material in Louisiana by Douglas (1974) who also reported the darter in impounded waters. Dickinson (1973, unpublished master's thesis, University of Tennessee, Knoxville, Tennessee) stated "The habitat of the harlequin darter is apparently rather swift riffles over fine gravel substrate."

We regard the deep riffle–detritus habitat, with or without sandy bottoms, as being preferred by *E. histrio* in western Kentucky, and can predict with some accuracy the occurence of individuals in such areas. We suspect that individuals collected in upland areas represent isolates that seek available habitat approximating the preferred lowland type. In all instances, the

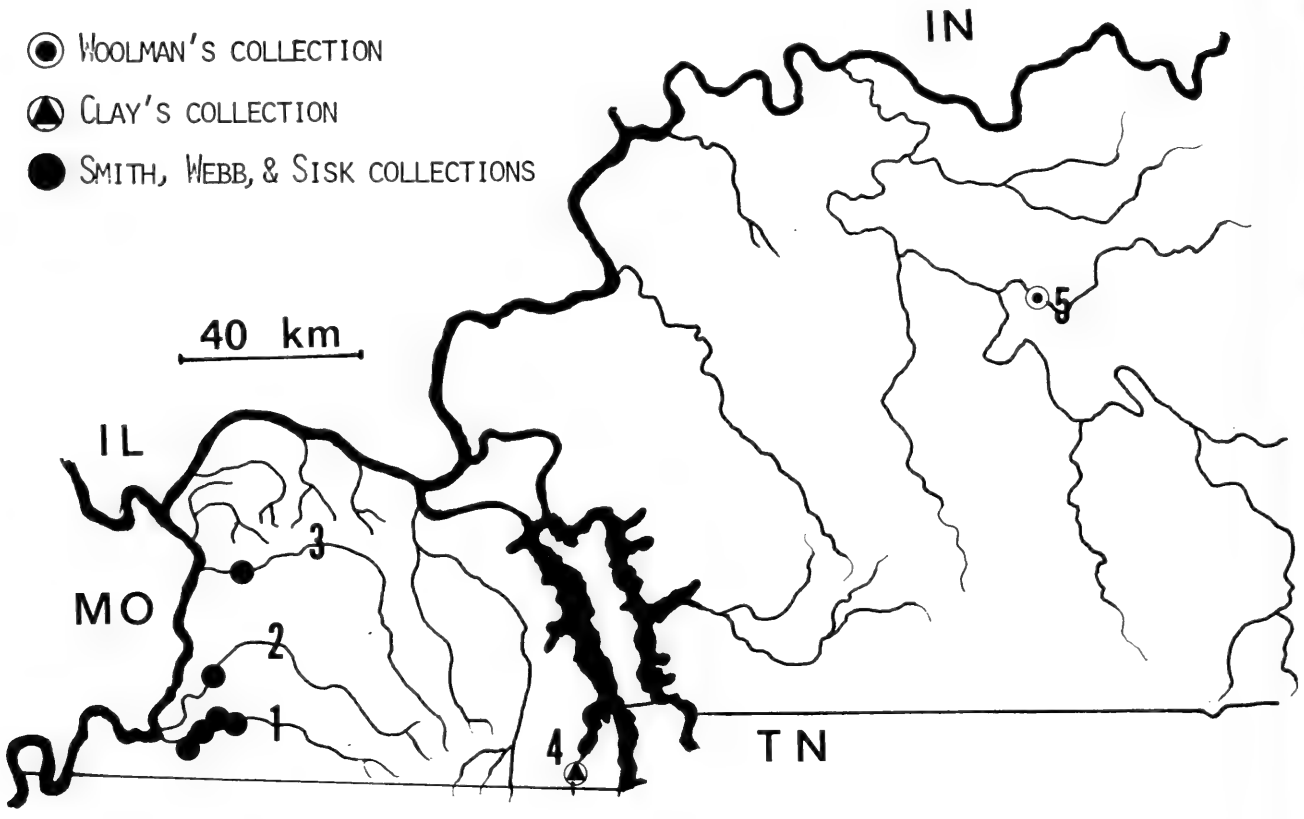

FIG. 1. Kentucky collections in which *Etheostoma histrio* has been taken. 1—Bayou de Chien; 2—Obion Crk.; 3—Mayfield Crk.; 4—Blood R.; 5—Rough R.

darter appears to require deep flowing waters.

Tsai (1968) has shown *E. histrio* to be largely confined to the Gulf Coastal Plain where it is nowhere common. With the exception of Woolman's (1892) collection, reports of this species from Kentucky are from the coastal plain region in the extreme western part of the state (Fig. 1). It appears that *E. histrio* is in danger of extirpation in the northern limits of its range, for the species is on the rare and endangered species list of Illinois, Kentucky, and Missouri (Miller 1972). Recent proposals by state, federal, and private interests to channelize and/or dredge parts of Bayou de Chien, Obion, and Mayfield creeks portends elimination of extant populations of *E. histrio* in those Kentucky streams.

LITERATURE CITED

DOUGLAS, N. H. 1974. Freshwater fishes of Louisiana. La. Wildl. Fish. Comm., Cliator's Pub. Div., Baton Rouge, La. 366 pp.

HUBBS, C. AND J. PIGG. 1972. Habitat preferences of the harlequin darter, *Etheostoma histrio*, in Texas and Oklahoma. Copeia 1972: 193–194

MILLER, R. R. 1972. Threatened freshwater fishes of the United States. Trans. Amer. Fish. Soc. 101(2):239–252

PFLIEGER, W. L. 1971. A distributional study of Missouri fishes. Mus. Nat. Hist., U. Kan. Publ. 20(3):225–570

SMITH, P. W. 1968. An assessment of changes in the fish fauna of two Illinois rivers and its bearing on their future. Trans. Ill. St. Acad. Sci. 61(1):31–45

SMITH, P. L., AND M. E. SISK. 1969. The fishes of west Kentucky. II. The fishes of Obion Creek. Trans. Ky. Acad. Sci. 30(3–4):60–68

TSAI, CHU-FA. 1968. Distribution of the harlequin darter, *Etheostoma histrio*. Copeia 1968:178–180

WEBB, D. H., AND M. E. SISK. 1975. The fishes of west Kentucky. III. The fishes of Bayou de Chien. Trans. Ky. Acad. Sci. 36(3–4): 63–70

WOOLMAN, A. J. 1892. Report of an examination of rivers of Kentucky with lists of the fishes obtained. Bull. U.S. Fish. Comm. 10: 249–288

A Review of the Genus *Blapstinus* (Coleoptera: Tenebrionidae)[1]

Jerry C. Davis
Department of Biology, Cumberland College, Williamsburg, Kentucky 40769

Abstract

This is an introduction to a revision of the genus *Blapstinus* in America north of Mexico. Authorship for the genus, generally attributed to Latreille, is reassigned to Sturm. *Blaps punctatus* Fabricius is interpreted as the monobasic type species. The genus *Blapstinus is* described and its distribution illustrated. Generic relationships are clarified with reference to generic identification. A key is presented to North American genera of the Tribe Pedinini.

Introduction

This is the first in a series of papers constituting a revision of the genus *Blapstinus* in America north of Mexico. The purpose of this paper is to bring together all available literature, clarify the authorship of the genus, describe the genus, discuss generic relationships, and present a key to North American genera of the Tribe Pedinini. Subsequent papers will deal with the morphology, bionomics, and systematics of the group.

The genus *Blapstinus* has been in a state of taxonomic confusion for over three-fourths of a century. Approximately 90 species have been assigned to the genus at one time or another. *Blapstinus* is a New World genus distributed from Canada through Argentina. Gebien (1937) listed 53 species for North America, 20 for Central America, and 15 for South America. Arnett (1962) attributed 52 species to the genus and listed *Blapstinus* as the third largest North American genus within the family Tenebrionidae. The genus belongs to the Tribe Pedinini, in which Arnett (1962) included 13 genera comprised of 92 North American species. Therefore, the genus *Blapstinus* has been credited with constituting over half the known species within the Tribe Pedinini.

Horn (1870) made the earliest attempt to monograph the genus. He presented a key to 14 North American species and included descriptions of 2 new species. Horn's key made considerable use of such taxonomic characters as color, pubescence, and luster of the integument which have made these beetles very difficult to identify. Although such characters were difficult for the taxonomist to describe and even more difficult for others to interpret, Horn's key probably was used extensively for a number of years.

Colonel Thomas Casey (1890) published the most extensive revision of the genus *Blapstinus*. He presented a key to 44 North American species, along with detailed descriptions of each species. Of the 44 species, Casey described 27 as new. Most problems encountered by recent investigators stem from trying to understand Casey's concept of a species or interpret his key. Not only did he use extensively such characters as color, pubescence, and luster of the integument, but he introduced other characters that require even greater perception to understand (to be discussed in a subsequent paper).

Although other workers have contributed to the group by the naming of new species, no workers other than Horn and Casey have attempted a detailed study of *Blapstinus*.

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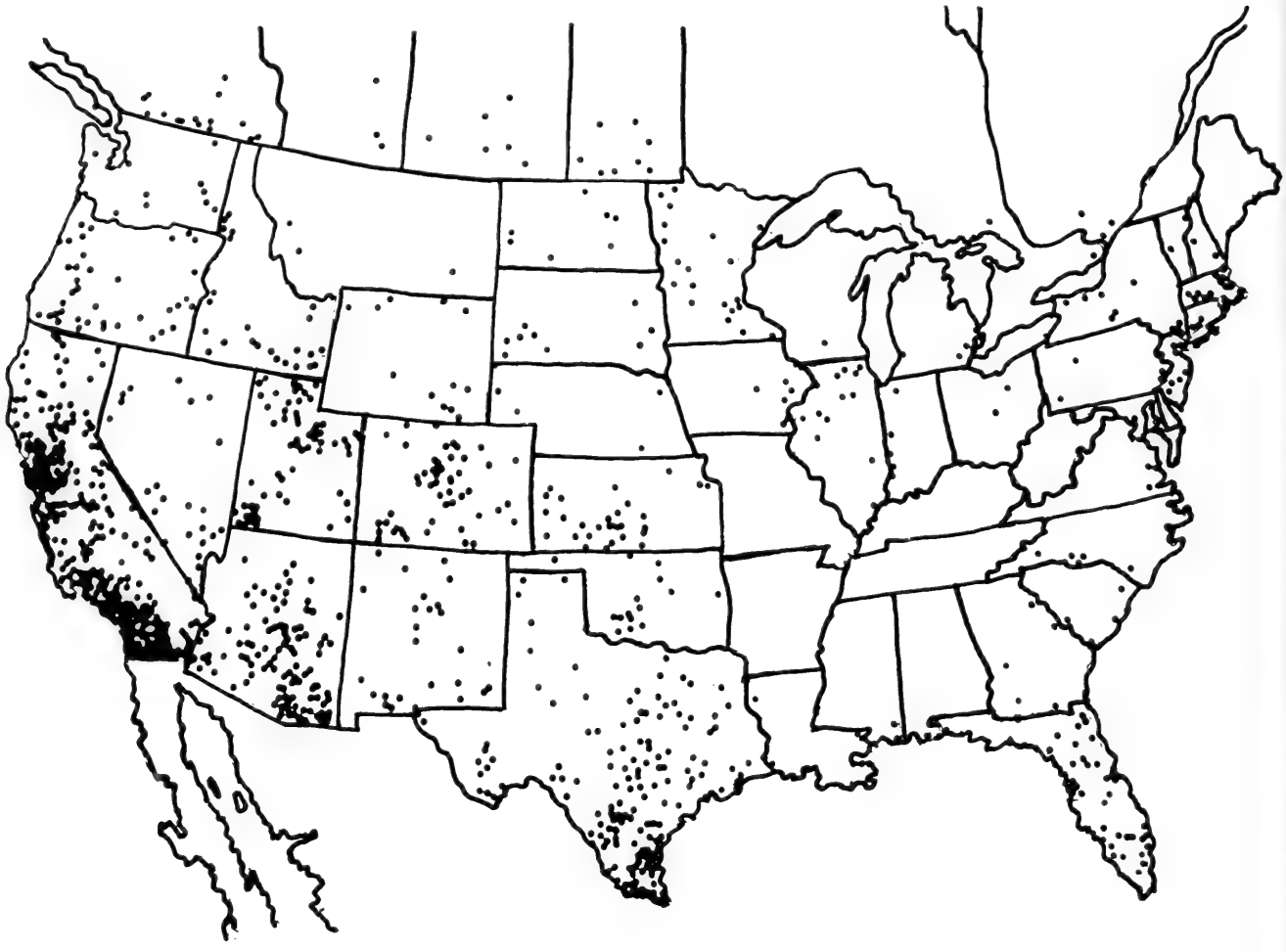

FIG. 1. Distribution of the genus *Blapstinus* in America north of Mexico.

Sciences of Philadelphia; F. Hasbrouck, Arizona State University at Tempe; I. LaRivers, University of Nevada, Reno; C. von Hayek, British Museum of Natural History; H. Leech, California Academy of Science; J. Powell, California Insect Survey; J. Campbell, Canadian National Collection; L. Pechuman, Cornell University; P. Clausen, University of Minnesota; G. Knowlton, Utah State University; R. Lavigne, University of Wyoming; J. Unzicker, Illinois Natural History Survey; J. Lawrence, Harvard University; C. Johnson, Northern Arizona University, Flagstaff; C. Triplehorn, Ohio State University; P. Oman, Oregon State University; R. Arnett, Purdue University; G. Byers, University of Kansas; G. Edwards, San Jose State University; H. Burke, Texas A&M University; F. Werner, University of Arizona; R. Schuster, University of California at Davis; S. Frommer, University of California at Riverside; W. Barr, University of Idaho; T. Spilman, United States National Museum; H. Howden, F. Moore, R. Berry, P. Petrovic, and W. Rosenberg.

Dr. A. Zhelochoutsev and Dr. P. Ardoin deserve thanks for making comparisons of specimens in the Soviet Union and France, respectively. Also, credit is due T. J. Spilman, USDA, for contributions concerning the literature.

The excellent photographic skill of Glenn Berkey, Ohio Agricultural Research and Development Center, is gratefully acknowledged.

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GENERIC HISTORY

The early history of the generic name *Blapstinus* is confusing and open to various interpretations. Several authors have been credited with authorship of the genus, but only 3 merit serious consideration, Dejean

FIG. 2. Head and prothorax of *Blapstinus substriatus*, dorsal view.

(1821), Sturm (1826), and Latreille (1829). Latreille has been most often credited with the genus, but Sturm is herein credited with the genus *Blapstinus* for the following reasons.

Dejean (1821), in his catalog of Coleoptera, listed "BLAPSTINUS, Dej." without generic description. Immediately beneath the generic name is listed "(BLAPS?

FIG. 3. Head and prothorax of *Blapstinus substriatus*, ventral view.

FIG. 4. *Blapstinus substriatus*, dorsal view.

Fabr.)," followed by 3 species names without description. Two of these species, "Striato-punctatus. *Dej.* id." and "Piceus. *Dej.* N.," are credited to Dejean and are nomina nuda. The third name is "Punctatus. *Sch. Fabr.* ? *Amer. Ins.*" The question mark puts the name in a state of species inquirenda, thereby excluding the name from being the type species. The generic name is therefore a nomen nudum and Dejean is not credited with the genus even though he apparently used the generic name *Blapstinus* first.

Sturm (1826), in his catalog of Coleoptera, listed "Blapstinus, Dej" without generic description. Included in that genus are 2 species, "punctato-striatus. *Billb. Amer. Ins.*" and "Punctatus. *Schonh.* (Blaps. *F.* ?) *Amer. Ins.*" The former name is a nomen nudum, but the latter is of significance. The question mark clearly refers to the old genus "Blaps," and Sturm was not indicating doubt about "Punctatus.

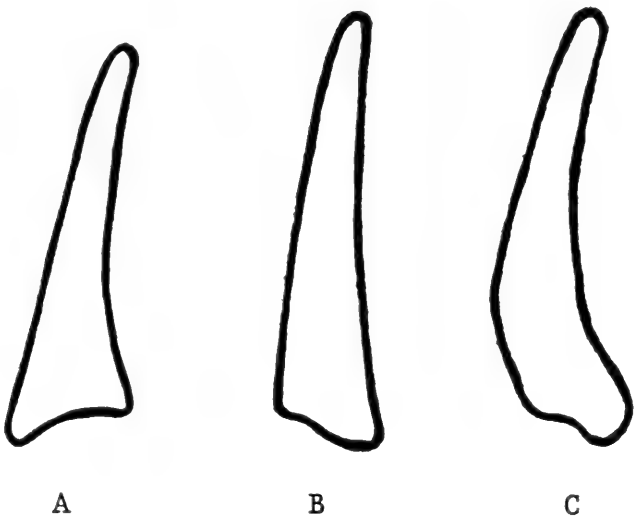

FIG. 5. Protibiae, anterior view. A. *Ulus*; B. *Blapstinus*; C. *Trichoton*.

Schonh.," but was referring to Schönherr (1806), who, under the name "BLAPS Punctatus," referred to Fabricius (1792) which was the original description of the species. In essence, Sturm cited *Blaps punctatus* Fabricius, 1792. This Fabrician species is interpreted as the monobasic type species of *Blapstinus* and the genus thereby attributed to Sturm.

Latreille (1829) listed "*Blapstine* (*Blapstinus*, Dej.)" with a short generic description. The spelling of the name obviously was in error. The only species he listed was "*Blaps tibidens* Schoenh.," a species originally described as "*Blaps tibidens* Quensel" in Schönherr (1806) and now in the genus *Sellio* Mulsant and Rey (1859a). If Latreille is given credit for the genus *Blapstinus*, the name *Blapstinus* would have to be synonymized with *Sellio*, and the genus now called *Blapstinus* would take the name of the oldest synonym, *Heteropus* LaPorte (1840).

SYNOPSIS OF GENERIC SYNONYMY

Blapstinus Sturm, 1826. Cat. Insecten-Sammlung, p. 101; Dejean, 1821:66; Latreille, 1829:21; Dejean, 1837:213; Waterhouse, 1845:34; Solier, 1851:232; Lacordaire, 1859:250; Mulsant and Rey, 1859a:180, 1859b:116; Horn, 1870:351; Casey, 1890:416, 1895:616.

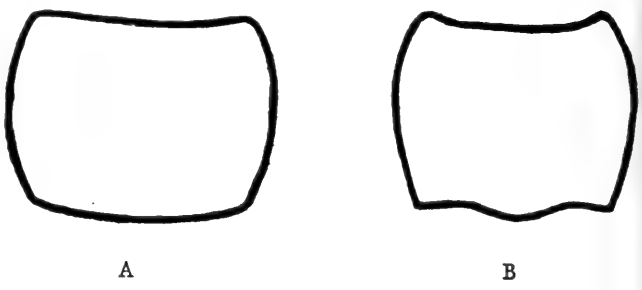

FIG. 6. Pronota, dorsal view. A. *Mecysmus*; B. *Blapstinus longulus*.

Type species: *Blaps punctatus* Fabricius, 1792:109; here designated.

Type locality: South America.

Heteropus LaPorte, 1840. Hist. Nat., p. 221. (Junior synonym of *Blapstinus*, Gebien, 1910:297).

Aspidius Mulsant and Rey, 1859a. Ann. Agric. Lyon, p. 187, 1859b:123. (Junior synonym of *Blapstinus*, Gebien, 1910: 297).

Lodinus Mulsant and Rey, 1859a. Ann. Agric. Lyon, p. 195, 1859b:131. (Junior synonym of *Blapstinus*, Gebien, 1910: 297).

DIAGNOSIS

Base of pronotum usually distinctly bisinuate; scutellum triangular; metathoracic wings usually well developed; protibiae straight and not produced externally at the apices; protarsi of male usually distinctly dilated.

DESCRIPTION

Length 3.5–9.5 mm.; usually oblong-oval; reddish-brown to black, head and pronotum often darker than elytra; integument usually shining; vestiture usually distinct and heterogeneous.

Head moderately convex; facial angles usually rounded; epistoma usually distinctly sinuate, clypeal suture usually visible; eyes completely divided into dorsal and ventral lobes, dorsal lobes separated by 3–5 times their maximum diameter, ventral lobes separated by 2–4 times their maximum diameter; antennae 11-segmented, slender, widest apically, third antennal segment usually

cylindrical and distinctly longer than segment 4 but distinctly shorter than segments 4 and 5 combined; head punctate, punctures usually coarse and sparse dorsally.

Pronotum usually distinctly convex; apical curvature usually prominent; lateral curvature usually distinct and evenly sinuate; basal curvature distinctly bisinuate; punctation variable, but usually distinct.

Elytra rounded at apex; interval width equal to 1–7 times diameter of the strial punctures, interval punctures usually fine; strial punctures usually deep.

Metathoracic wings usually well developed, fully as long as the abdomen.

Abdomen punctate; an impression usually present toward apex of the fifth abdominal segment.

Male with a basal abdominal impression usually present; anterior tarsi usually distinctly dilated; subgenital sternite usually feebly or not at all emarginate apically; tegmen of aedeagus strongly curved in lateral view, parameres fused dorsally and ventrally to form a sclerotized ring, basal piece fused dorsally and ventrally.

DISTRIBUTION

The more than 20,000 specimens examined during the course of this study indicate that the genus *Blapstinus* is widely distributed in the United States (Fig. 1). Each dot on the map represents a locality, not a numerical collection. Although the specimens have been collected in almost every state, the beetles are most likely to be found in the Southwest. Many species of *Blapstinus* are commonly collected in large numbers. Several collections studied contained series of more than 100 specimens.

GENERIC RELATIONSHIPS

A dozen genera, including *Blapstinus*, usually are included in the family Tenebrionidae within the Tribe Pedinini. Most of these genera share the following characteristics: oval, oblong-oval; eyes usually completely divided into dorsal and ventral lobes (Figs. 2, 3); third antennal segment elongate (Figs. 2, 3, 4); epistoma emarginate (Fig. 2); apical segment of maxillary palps triangular or securiform (Fig. 2); metathoracic wings well developed, reduced, rudimentary, or absent; pro- and mesotarsi usually distinctly dilated (Figs. 2, 3, 4); tarsi spongy, spinose, or setose ventrally (Fig. 3).

Blapstinus Sturm is most often confused with the genera *Trichoton* Hope, *Ulus* Horn, and *Mecysmus* Horn. *Trichoton* may easily be distinguished from *Blapstinus* by the distinctly bent protibiae (Fig. 5C). *Ulus* differs from *Blapstinus* in having the protibiae produced externally at the apices (Fig. 5A). The protibiae of *Blapstinus* are straight (Fig. 5B).

One species, *Blapstinus longulus* LeConte, is commonly confused with the genus *Mecysmus*. However, the base of the pronotum is bisinuate and about as wide as the base of the elytra in *B. longulus* (Fig. 6B); the base of the pronotum in *Mecysmus* is not bisinuate and is much narrower than the base of the elytra (Fig. 6A).

The following is a key, modified from Arnett (1962), to genera of the Tribe Pedinini.

KEY TO NORTH AMERICAN GENERA OF THE TRIBE PEDININI

1.	Scutellum triangular (Fig. 4); metathoracic wings often well developed; protarsi of male usually distinctly dilated (Figs. 2, 3, 4)	2
1′.	Scutellum very broad and short; metathoracic wings absent; protarsi of male not dilated	7
2 (1).	Base of pronotum usually distinctly bisinuate (Figs. 4, 6B)	3
2′.	Base of pronotum not bisinuate	5
3 (2).	Protibiae bent (Fig. 5C)	*Trichoton* Hope
3′.	Protibiae straight (Figs. 5A, B)	4
4 (3′).	Protibiae produced externally at apices (Fig. 5A); body generally oval, laterally fimbriate	*Ulus* Horn
4′.	Protibiae not produced externally at apices (Fig. 5B); body oval, oblong-oval or elongate-oval, not laterally fimbriate	*Blapstinus* Sturm
5 (2′).	Base of pronotum evenly arcuate	*Aconobius* Casey
5′.	Base of pronotum straight	6

6 (5′). Basal width of pronotum equal to basal width of elytra; body broadly oval and strongly convex ..... *Cybotus* Casey

6′. Basal width of pronotum less than basal width of elytra; body elongate and subdepressed ..... *Mecysmus* Horn

7 (1′). Prothorax densely fimbriate laterally 8

7′. Prothorax not fimbriate laterally 9

8 (7). Protibiae narrow; body narrow and parallel ..... *Conibiosoma* Casey

8′. Protibiae broad; body stout and oblong-oval ..... *Notibius* LeConte

9 (7′). Elytra sulcate 10

9′. Elytra not sulcate ..... *Conibius* LeConte

10 (9′). Elytral intervals acutely ribbed ..... *Tonibiastes* Casey

10′. Elytral intervals convex 11

11 (10′). Last three antennal segments abruptly clubbed ..... *Nocibiotes* Casey

11′. Last three antennal segments freely differentiated ..... *Tonibius* Casey

LITERATURE CITED

ARNETT, R. H. 1962. Polyphaga, series Cucujiformia, Pt. 5, Fasc. 73, 52 pp. *In* The Beetles of the United States, Catholic Univ. Amer. Press, Washington, D.C. 1112 pp.

CASEY, T. L. 1890. Coleopterological notices, II. Ann. N. Y. Acad. Sci. 5:307–504.

————. 1895. Coleopterological notices, VI. Ann. N. Y. Acad. Sci. 8:435–838.

DEJEAN, P. F. M. A. 1821. Catalogue de la collection de Coléoptères de M. le baron Dejean. Paris, France 136 pp.

————. 1837. Catalogue des Coléoptères de la collection de M. le comte Dejean. Troisieme edition, revue, corrigee et augmentee. Paris, France 384 pp.

FABRICIUS, J. E. 1792. Entomologia systematica, Vol. 1. 538 pp.

GEBIEN, H. 1910. Coleoptorum Catalogus, pars 15, Tenebrionidae, I, Vol. XVIII. 166 pp.

HORN, G. H. 1870. Revision of the Tenebrionidae of America, North of Mexico. Trans. Amer. Philos. Soc. 14(2):253–404.

LACORDAIRE, J. T. 1859. Histoire naturelle des insects. Genera des Coléoptères, etc. Paris, France, Vol. 5. 750 pp.

LAPORTE, F. L. N. C. 1840. Histoire naturelle des animaux articulés. Paris, France, Vol. 1. 324 pp.

LATREILLE, P. A. 1829. Les crustaces, les arachnides et les insects, distribues en famille naturelles ouvrage formant les tomes 4 et 5 de celue de M. le Baron Cuvier sur le Regne animal (deuxieme edition). Paris, France, Vol. 1. 584 pp.

MULSANT, E., AND C. REY. 1859a. Essai d'une division des derniers melasomes. Ann. Soc. Agric. Lyon 3(3):129–201.

————, AND ————. 1859b. Essai d'une division des derniers melasomes. Opusc. Ent. 9:123–180.

SCHÖNHERR, C. J. 1806. Synonymia insectorum, oder: Versuch einer Synonymie aller bisher bekanten Insecten: nach Fabricii Systema Eleutheratorum geordnet. Vol. 1. 293 pp.

SOLIER, A. J. J. 1851. Orden III. Coleopteros. *In* Gay, Historia fisica y politica de Chile. Vol. 5. 282 pp.

STURM, J. 1826. Catalog meiner Insecten-Sammlung Erster Theil, Käfer, Nürnberg 207 pp.

WATERHOUSE, G. R. 1845. Descriptions of coleopterous insects collected by Charles Darwin, Esq., in the Galapagos Islands. Ann. Mag. Nat. Hist. 16:19–41.

The Occurrence of *Ichthyophthirius multifilis* (Ciliata: Hymenostomatida) in Kentucky Waters.[1]

THOMAS R. KOZEL
Department of Biology, University of Louisville, Louisville, Kentucky 40208

ABSTRACT

This is the first report of *Ichthyophthirius multifilis*, parasitizing the blackstripe topminnow *Fundulus notatus*. Data indicating site preferences and intensities of infestation of the parasite on its host are based on the examination of 10 males and 6 females. The caudal fin, head, and upper body surface are implicated as the most heavily parasitized areas on the host. Smaller fish were more heavily infested than larger fish. A brief history of the occurrence of *I. multifilis* in Kentucky waters is also included along with its distribution in nearby states.

INTRODUCTION

Ichthyophthirius multifilis is a cosmopolitan protozoan ectoparasite capable of infesting a wide variety of freshwater fishes. Until the present time, however, there have been no published records of the organism's occurrence in Kentucky waters. *I. multifilis*, known colloquially as "ich," most often parasitizes aquarium and cultured fishes, but its appearance in natural systems is by no means uncommon. Outbreaks of the disease, ichthyophthiriasis, usually occur in warm waters where host density is high and flow rate low.

The present report is based on a study of 10 male and 6 female blackstripe topminnows *Fundulus notatus* given to the author by Mr. James Pitts, Louisville, Kentucky. An outbreak of ichthyophthiriasis was suspected by Mr. Pitts and later confirmed by me.

In Kentucky, prior to the present observations, *I. multifilis* had been noticed on 2 occasions, both of which have been recorded but never published. Mr. Charles C. Bowers, Jr., Director, Division of Fisheries, Kentucky Department of Fish and Wildlife Resources (pers. comm.), indicated that an outbreak of ichthyophthiriasis occurred among channel catfish *Ictalurus punctatus* at the federal hatchery near Frankfort, Kentucky, but he did not know the exact date. Complete control of the infestation was obtained with chemicals. The second report described a fish kill that extended from Campbell through Lewis counties on the Ohio River, including the mouths of some of its tributaries, during the spring of 1971. Mr. Bonny Laflin of the Fisheries Division and Mr. W. A. Rogers, Leader, Southeastern Cooperative Fish Disease Project at Auburn, Alabama (pers. comm.), revealed that although many species were observed dead, only gizzard shad *Dorosoma cepedianum*, bluegill *Lepomis macrochirus*, and freshwater drum *Aplodinotus grunniens*, were actually parasitized by *I. multifilis*.

The presence of the parasite in the waters of nearby states has been reported by Allison and Kelly (1963) in the Coosa River system of northeastern Alabama where gizzard shad, and threadfin shad *D. petenense*, as well as 9 other species were affected; Pearson (1932) reported an epizootic which involved 9 species in an Indianapolis municipal park pond; Kudo (1934), from a large reservoir near Peoria, Illinois, involving carp *Cyprinus carpio*; and Elser (1955), at Deep Creek Lake impoundment in Maryland, with perch *Perca flavescens*.

ACKNOWLEDGMENTS

I wish to thank Dr. Fred H. Whittaker, Department of Biology, University of Louisville for his encouragement and review of the manuscript, and Dr. Andrew Miller for statistical assistance.

[1] Contribution No. 176 (new series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

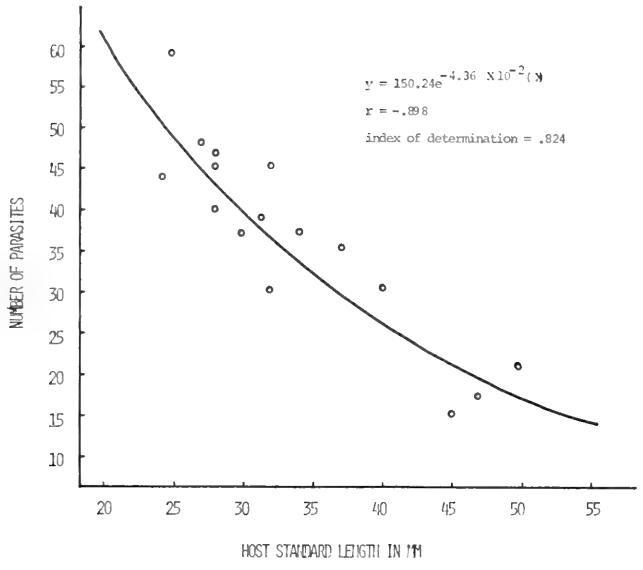

FIG. 1. Total number of parasites per fish plotted against standard length of *F. notatus*.

MATERIALS AND METHODS

On 18 November 1973, during the collection of various minnow species with seine and dipnet from the area surrounding the confluence of Pope Lick Creek and Floyds Fork Creek, near the Pope Lick Road bridge, in southeastern Jefferson County, Mr. James Pitts obtained 16 blackstripe topminnows, one of which apparently had ichthyophthiriasis. All specimens were captured over sand and gravel near banks overhung with vegetation. Normal fall flow and turbidity conditions prevailed. The fish were transported live and held in a 37.85-1 aquarium for 5 days at 15–18 C until I could examine them. During that time, the remaining 15 fish exhibited gross signs of ichthyophthiriasis.

Host specimens were sacrificed by pithing immediately behind the parietal spot, and the live parasites examined in situ with the aid of a 45 × binocular dissecting microscope. Aquarium water from the collection site was used to keep the host epithelium and parasites moist during the examination. Site preferences and the numbers of parasites on each host were determined. To facilitate counting the individual ciliates, the body of the host was divided into 5 sections, the head, a left and right upper section, and a left and right lower section. The head region was that portion anterior to a line perpendicular to the lateral stripe, and tangential to the rear margin of the orbit. Upper body surfaces were those dorsal to the upper margin of the lateral stripe and posterior to the head region. Lower body surfaces were those ventral to the upper margin of the lateral stripe and posterior to the head region. Right and left sections were determined by the midline. After body and fin surfaces were examined, the gills were excised and searched for *I. multifilis*. Individual parasites freed from epithelial cysts with a dissecting needle were placed in depression slides with 2 drops of aquarium water and examined microscopically.

Specimens of the parasites were fixed in Schaudinn's solution, stained with Harris' hematoxylin, and mounted in Euparol.

The keys of Hoffman (1967) and description by Meyer (1969) were used to aid in identification of the organism.

RESULTS

Ten male and 6 female *F. notatus* were infested with *I. multifilis*. Based on reproduction times for the ciliate in the cyst from data of Bauer (1959), it is concluded that all 16 fish were infested at time of capture and not subsequently from the aquarium in which they were held. At the 15–18 C temperature, the life cycle would take approximately 2 weeks to complete, whereas all the present fish developed visible signs of ichthyophthiriasis within 5 days.

I. multifilis occurred most often on the caudal fin, head, and upper body surface of its host (Table 1).

The relationship between the standard length of *F. notatus* and the number of parasites found on each fish is shown in Fig. 1. With 14 degrees of freedom, the correlation coefficient $r = -.898$, is significant at the 0.01 level. A least squares curve fit indicates that a curve represented by the formula $y = ae^{bx}$, where $e = 2.718$, $a = 150.24$, and $b = -4.36 \times 10^{-2}$, best represents the data. The index of determination

Table 1.—Distribution of parasites on 16 *F. notatus*

Location	Number of parasites per location		
	Total	Mean	% of total
Left pectoral	19	1.00	3.23
Right pectoral	20	1.50	3.40
Left pelvic	12	0.67	2.04
Right pelvic	18	1.33	3.06
Anal	26	1.83	4.41
Dorsal	28	2.50	4.75
Caudal	108	6.33	18.34
Head	84	4.67	14.26
Left upper	85	3.33	14.43
Right upper	90	3.58	15.28
Left lower	48	2.00	8.15
Right lower	39	1.17	6.62
Gills	12	0.67	2.04
	589	30.83	

for this curve is .824. Smaller fish carried more parasites than larger fish.

Host behavioral manifestations due to ichthyophthiriasis included "clamping" or the holding of fins close to the body, sluggish swimming motions and reduced general activity, residing near sides and bottom of the aquarium, and wagging movements of the caudal fin and peduncle areas. Since fish were sacrificed on the day the author received them, no feeding behavior was observed.

Discussion

This report constitutes the first record of occurrence of *I. multifilis* on the blackstripe topminnow *F. notatus* and is the first record of occurrence of the parasite from stream waters in Kentucky. It helps link the geographic distribution north and south of the Ohio River.

Parker (1965, unpublished doctoral dissertation, University of Maryland, College Park, Maryland), Hines and Spira (1973), Meyer (1969), Wolf (1938), and Paperna (1972) performed site preference analyses of *I. multifilis* on its host, but none are as detailed as the present work. Hines and Spira (1973) commented on the preponderance of organisms infesting the dorsal surface of *C. corpio*, but offer no explanation. Unfortunately, without histological examination of the hosts' body surfaces, no complete explanation can be given.

Although the gills are seemingly excellent attachment sites, and Meyer (1969) stated that the golden shiner *Notemigonus crysoleucas* often has heavy infestations on them and nowhere else, *F. notatus* examined here had few organisms on the gills.

Since length may be an indicator of age, it appears that younger fish had a more severe infestation than older specimens. The work of Bauer (1959) and Hines and Spira (1974) indicate that immunity to *I. multifilis* may be acquired through previous infestation. In carp, Hines and Spira (1974) found that fish remained free of the parasite 8 months after an initial infestation. The older hosts examined here may have been previously infested with *I. multifilis* and therefore exhibited at least partial immunity to reinfestation. The younger fish may not have been previously exposed.

Literature Cited

Allison, R., and H. D. Kelly. 1963. An epizootic of *Ichthyophthirius multifilis* in a river fish population. Prog. Fish-Cult. 25(3): 149–150.

Bauer, O. N. 1959. Parasites of freshwater fish and the biological basis for their control. Bulletin of the State Scientific Research Institute of Lake and River Fisheries, Vol. XLIX. Leningrad. Trans. by L. Kochva. 236 pp.

Elser, H. J. 1955. An epizootic of ichthyophthiriasis among fishes in a large reservoir. Prog. Fish-Cult. 17(3):132–133.

Hines, R. S., and D. T. Spira. 1973. *Ichthyophthirius multifilis* (Fouquet) in the mirror carp, *Cyprinus carpio* L. I. Course of infection. J. Fish Biol. 5(3):385–392.

————, and ————. 1974. Ichthyophthiriasis in the mirror carp *Cyprinus carpio* (L). V. Acquired immunity. J. Fish Biol. 6(4): 373–378.

Hoffman, G. L. 1967. Parasites of North American freshwater fishes. Univ. Calif. Press, Berkeley, Calif. 486 pp.

Kudo, R. R. 1934. Studies on some protozoan parasites of fishes of Illinois. Ill. Biol. Monogr. 13(1):1–44.

Meyer, F. P. 1969. Parasites of freshwater fish. II. Protozoa. 3. *Ichthyophthirius multifilis*. Fish Disease Leaflet 2. U.S. Dept. Int., Washington, D.C. 4 pp.

PAPERNA, I. 1972. Infection by *Ichthyopthirius multifilis* of fish in Uganda. Prog. Fish-Cult. 34(3):162–164.

PEARSON, N. E. 1932. Ichthyophthiriasis among the fishes of a pond in Indianapolis. Proc. Ind. Acad. Sci. 41(1931):455–463.

WOLF, L. E. 1938. Ichthyophthiriasis in a trout hatchery. Prog. Fish-Cult., Memo. 131 pp.

ACADEMY AFFAIRS

The Sixty-First Annual Business Meeting of the Kentucky Academy of Science, University of Louisville, Health Science Center, Louisville, Kentucky

7 and 8 November 1975

Hosts: Drs. Charles E. Kupchella and John R. Meyer

Minutes of the Annual Business Meeting

President Ellis V. Brown called the meeting to order at 0815, 8 November, in the Library and Commons Building Auditorium. About 60 members were in attendance.

Secretary Prins moved that the minutes of the 1974 Annual Business meeting at Centre College as recorded in TRANSACTIONS Vol 35 (3–4) be approved. After a second from the floor the motion carried. Secretary Prins then announced that the membership count stood at about 510 which represents a negligible change from the 1974 Count. After a motion and second from the floor, new members (approximately 40) were accepted into the Academy by a unanimous vote.

The Treasurer's report was distributed to the members present. The report was certified as accurate by the audit committee consisting of Drs. W. G. Lloyd, D. H. Puckett, and Gordon Wilson, Jr. After a motion by B. Branson and a second by M. Russell, the Treasurer's report was accepted.

Treasurer's Report to Audit Committee
Kentucky Academy of Science

October 8, 1974–September 29, 1975

Cash in Citizens National Bank Bowling Green, Kentucky		$ 2,915.12[1]
RECEIPTS		
Subsidy from State	$3,000.00	
Membership Dues	2,147.00	
Reprints	37.00	
Annual Meeting	915.40	
Transactions Subscriptions	124.50	
University of Louisville Purchase of Transactions	900.00	
AAAS Research Grant	124.00	$ 7,247.90
		$10,163.02
DISBURSEMENTS		
Research Grants	124.00	
Annual Meeting	742.77	
Publications of Transactions	3,267.90	
AAAS Dues	23.75	
Stationery-Printing	68.97	
JKAS	300.00	
Reprints	285.86	
Miscellaneous	2.50	$ 4,815.75
		$ 5,347.27
Cash in Citizens National Bank		$ 5,347.27
Savings Account—Lexington Federal Savings & Loan		$ 1,208.82
Botany Grant		$ 679.28
TOTAL ASSETS		$ 7,235.37

[1] NOTE: $2,915.12 carry-over from 1974 is arrived at by totaling $2,738.51 (cash in Citizens National Bank) and $176.61 (Thomas Hunt Morgan Fund).

Dr. Brown next called for reports from standing committees. Copies of the reports were distributed to the members present.

1. **Committee on Membership.** No report.

2. **Committee on Publications.** Two major changes have been initiated in the past two years. One change is the format which has been very well received. The other is that publication and distribution dates have been stabilized. The Transactions are now mailed in March and in September of the year in which they are published.

3. **Committee on Legislation.** No report.

4. **Committee on Distribution of Research Funds** (Wm. L. Dixon, Patricia Malik, and Jerry F. Howell, Jr.). Nominations for grants were:

a) Joseph T. Collins ($100.00) for a *Bibliography of the amphibians and reptiles of Kentucky.*
b) Charles V. Covell, Jr. ($32.00) for a *Moth Survey of the Red River Gorge.*

There were 5 applications for grants this year. The recommendation of the Committee for these two awards as accepted.

Reports from other committees were then called for by President Brown.

1. **The Junior Academy.** Under the active leadership of Herbert Leopold (WKU) the Academy has conducted regional seminars, the last (Nov 15) being related to the theme, "Kentucky and the Energy Crisis." Seven institutions hosted the seminars this fall. The books of the Junior Academy were found in order by the audit committee, consisting of L. P. Elliott, Wm. G. Buckman, and H. A. Leopold. The balance on hand as of October 19 was $1,132.20.

2. **AAAS Representative's Report.** None

3. **The Teachers Certification Committee.** A report entitled "State Funding for Science Education in the Public School System" was mailed to the membership earlier for consideration by the chairman, Dr. Ted George. A motion and second to accept the report carried unanimously (the full report is included in the Secretary's book).

4. **The Board of Directors.** Dr. John C. Philley (1975 Chairman) reported that the Board was continuing to define its role and, as a follow up to recommendations made by the 1974 Board, was proposing changes in the Constitution. These changes, mailed to the membership earlier, were unanimously approved by the membership. The Articles, as amended, read as follows:

Art III, Section 3. The President-elect shall succeed the retiring President. In case he is unable to assume office, a President shall be elected at the fall meeting. The President-elect shall be an ex-officio member of the board of directors.

Art IV, Section 1. The President shall discharge the usual duties of a presiding officer at all General Meetings of the Academy, the Executive Committee and the Council. He shall keep himself constantly informed on the affairs of the Academy and on its acts and those of its officers and he shall cause the provisions of the Constitution and By-Laws to be faithfully carried into effect. He shall be a member of the board of directors.

Art V, Section 2. The Executive Committee shall execute and administer the affairs of the Academy during intervals between the various sessions of the organization, except those duties assigned to the Council, and shall fill vacancies.

Art XI, Section 1. There shall be a Board of Directors consisting of eight elected members, The President, The President-elect, and the Immediate Past President, the last two as ex-officio members.

Art XI, Section 2. Two members shall be elected at each fall meeting for a four-year term.

Art XI, Section 4. The Board of Directors shall have the responsibility for the overall direction of the affairs of the Academy. In said Board shall be vested and by said Board shall be exercised all the ordinary and appropriate powers and functions of the Academy. Said Board shall annually choose from their members a Chairman and a Secretary to act as such, respectively, until their successors are elected.

Art XI, Section 5. A quorum shall consist of a majority of the voting members of the board.

The Board has also recommended that the Kentucky Academy of Science recognize outstanding scientists in Kentucky, conduct special symposia at annual meetings and promote institutions to become contributing members—as per Art II, Section 6—of the Academy. The agenda of the Board is such that many very constructive contributions can be made by it in the near future (the full report is recorded in the Secretary's book).

Dr. Don Batch was invited to submit resolutions from the resolutions committee. All resolutions were passed unanimously.

RESOLUTIONS

Whereas, the University of Louisville, Health Sciences Center has graciously served as the Host Institution for the Sixty-first Annual Meeting of the Kentucky Academy of Science, and whereas Dr. Charles Kupchella and Dr. John Meyer, members of the Hospitality Committee, and other personnel of the Health Sciences Center have all worked diligently to make the meeting a success and,

Whereas, the Health Sciences Center has made outstanding contributions to scientific thought and leadership;

Therefore, be it resolved:

1. that the Kentucky Academy of Science express its appreciation to the University of Louisville, Health Sciences Center and the above individuals, and that the Academy's Secretary be instructed to so inform them.
2. That the Kentucky Academy of Science congratulate the University of Louisville, Health Sciences Center as an outstanding institution of higher education in Kentucky and our nation and for the promotion of science through clinical teaching, research, and public service.

Whereas, it has come to the attention of the Academy that a new funding regulation for public schools, namely Senate Bill 280, has funding inequities as far as science education is concerned; and whereas the Academy feels that the good health of science in Kentucky can be improved by stronger science education in the public schools; Therefore, be it resolved:

that the president of the Kentucky Academy of Science be empowered to appoint an Ad Hoc Committee to study the pupil weighting factors set out in Senate Bill No. 280 and work with other science and education groups in Kentucky with respect to making a proposal to the state legislature to equalize the funding of science education with other funding levels as outlined in Senate Bill No. 280.

The New slate of officers was submitted by the Nominating Committee consisting of Paul Sears (chm), L. A. Krumholz, and M. W. Russell, as follows:

President Elect: Charles Payne, Morehead State University
Vice President: Charles E. Kupchella, University of Louisville
Secretary: Rudolph Prins, Western Kentucky University
Treasurer: Wayne Hoffman, Western Kentucky University
Representative to A.A.A.S. Council, to 1978: Branley A. Branson, Eastern Kentucky University
Member, Board of Directors, to 1979: Thomas B. Calhoon, University of Louisville
Member, Board of Directors, to 1979: Harold Eversmeyer, Murray State University

The floor was then open for additional nominations. A motion and second from the floor to cease nominations passed and Dr. Sears (V. Wiedeman second) moved that the officers be accepted by acclamation. The motion passed unanimously and the president ordered the Secretary to declare the nominees elected by acclamation.

There being no further business Dr. E. Brown announced that the 1976 Annual Meeting would be at the University of Kentucky and invitations for 1977 meetings would be welcomed. He requested that these be submitted to the Executive Committee by May 1976.

Dr. E. Brown then turned the meeting over to the new president of the K.A.S., Dr. Frederick M. Brown, Chief Psychologist, Kentucky State Hospital, Danville, KY.

Dr. Brown briefly reviewed some accomplishments of the K.A.S. over the last few years and suggested that the Academy now should start to move toward more wide recognition and communicate, educate, and coordinate State efforts with regard to scientific matters. The Academy, in short, should move from a rear guard to a leading posture in scientific matters within the state by becoming more involved in public and political issues.

Dr. Brown proposed to establish two ad hoc committees in 1976:

1) Public Science Education Committee. This committee will review pending legislation and directives relative to science education within the state.
2) State Governmental Science advisory Committee. This committee will communicate with the governor and other members of state government on matters of concern. Dr. Brown stated that he would call the governor's attention to this committee and offer its services.

There being no further business the meeting adjourned, after a motion and second from the floor, at 0915.

Rudolph Prins, Secretary
Kentucky Academy of Science

PROGRAM

Friday, 7 November 1975

12:00–5:00 PM REGISTRATION, Lobby, First Floor, Library, and Commons Building.

1:30–2:30 PM STANDING COMMITTEE MEETINGS:
- Membership Committee: Health Sciences Building, Room 109
- Legislative Committee: Health Sciences Building, Room 115
- AAAS Grants Committee: Health Sciences Building, Room 121
- Publications Committee: Health Sciences Building, Room 128
- Resolutions Committee: Health Sciences Building, Room 209
- Nominations Committee: Health Sciences Building, Room 215
- Board of Directors: Library and Commons Building, Room 105

1:00–6:00 PM SCIENTIFIC EXHIBITS Main Auditorium Lobby

1:00–4:00 PM SECTIONAL MEETINGS (see following pages)

2:30–4:00 PM KAS COUNCIL MEETING: Library and Commons Building, Room 105

4:00–5:30 PM PLENARY SESSION: Library and Commons Building, Auditorium

6:30–7:30 PM RECEPTION HOUR: Holiday Inn, Midtown

7:30 PM KAS ANNUAL BANQUET: Holiday Inn, Midtown
(NOTE: Pick up tickets at Registration desk)

Saturday, 8 November 1975

7:00–9:00 AM BREAKFAST SERVICE: Library and Commons Building, Cafeteria

8:00–10:00 AM REGISTRATION: Lobby, First Floor, Library and Commons Building

8:00–8:30 AM ANNUAL BUSINESS MEETING: Library and Commons Building, Audtiorium

9:30 AM SECTIONAL MEETINGS: see below

11:00–2:00 PM CAFETERIA SERVICE: Library and Commons Building, Cafeteria

1:00 PM OPEN HOUSE BY DEPARTMENTS

ANTHROPOLOGY
Richard Levy (Chairman)
M. B. Collins (Secretary)

No Program for 1975 Meeting

BOTANY AND MICROBIOLOGY

Room 302, Health Sciences Building
Harold E. Eversmeyer, Chairman, Presiding
Joe E. Winstead, Secretary

Saturday, 8 November

9:45 Comparison of media for quantitating airborne microbes. M. S. Hudnall, Larry P. Elliott, and Lewis B. Lockwood, Department of Biology, Western Kentucky University.

10:00 The occurrence of gibberellin-like substances in *Azomonas macrocytogenes* and *Azomonas agilis*. James W. Freeman and Robert Creek, Department of Biological Sciences, Eastern Kentucky University.

10:15 Corticolous bryophyte communities at Mountain Lake, Virginia. Susan M. Moyle, Department of Biology, Centre College of Kentucky.

10:30 Morphological and anatomical differences in populations of *Carpinus caroliniana*. Gordon I. Wardell and Joe E. Winstead, Department of Biology, Western Kentucky University.

10:45 New and interesting plants of the Cyperaceae in western Kentucky. Raymond Athey, Paducah, Kentucky.

11:00 The quality of water received as precipitation on a forested watershed in eastern Kentucky. Michael Shearer, George Coltharp, Robert Wittwer, and Roger Horseman, Department of Forestry, University of Kentucky.

11:15 Forest composition of the Rock Creek Natural Landmark, Laurel County, Kentucky. Margaret E. Ringland and Joe E. Winstead, Department of Biology, Western Kentucky University.

11:30 Notes on the flora and vegetation of swamp forests around the southeastern Bluegrass. Howard Setser, Leslie Mead, Morehead State University, and Willem Meijer, Department of Botany, University of Kentucky.

11:45 Corn Creek; a migratory waystation for woody plants on the Ohio River. Ronald R. Van Stockum, Jr., Department of Biology, University of Louisville.

12:00 Field notes in Kentucky plants 1974–1975. Johnnie B. Varner, Harrison County High School.

12:15 Threatened and endangered vegetational and floristic elements in Kentucky—what we can do to preserve them. William H. Martin, General Studies Science Program, Eastern Kentucky University.

12:30 A computer data bank for the flora of Kentucky. Frank Becker, (sponsored by Willem Meijer, Department of Botany, University of Kentucky).

12:45 Election of Officers for 1975–1976.

CHEMISTRY

Room, 202, Health Sciences Building
James C. Letton, Chairman, Presiding
Joseph Hendon, Secretary

Friday, 7 November

1:00 Sectional Business Meeting.

1:15 A water quality study of the Salt River in Spencer County, Kentucky. Andrew Miller, Water Resources Laboratory, University of Louisville. (Louis A. Krumholz, Sponsor).

1:30 Viscoelastic properties of polypeptide liquid crystals: relation to biological structures and sensitivity. Donald B. Dupre, Department of Chemistry, University of Louisville.

1:45 Olefin-ligand displacement from (*octa-hapto*-Benzonorbornadiene) dicarbonylchromium. B. A. Howell and W. S. Trahanovsky, Department of Chemistry, University of Louisville.

2:00 Orgonometallic conformational equilibria. The orientation of π-allyl ligand in π-cyclopentadienyl and π-indenyl complexes of iron and ruthenium. J. W. Faller, Bryce V. Johnson, and T. P. Dryja, Department of Chemistry, University of Louisville.

2:15 Monitoring of hormone solid phase synthesis by ^{14}C labeled amino acids: implications for protein synthesis. Arno F. Spatola and Marta Gwinn, Department of Chemistry, University of Louisville.

2:30 Functionalization and reactions of carcinogenic azoxyalkane analogs. K. G. Taylor and M. S. Clark, Department of Chemistry, University of Louisville.

2:45 Jahn–Teller effect in coordination compounds. C. A. Trapp and Y. C. Park, Department of Chemistry, University of Louisville.

3:00 Cycloaddition chemistry of 1-azadienes. J. L. Wong and C. M. Gladstone, Department of Chemistry, University of Louisville.

3:15 Inorganic crystallization chromatography. Preston Miles and W. F. Wagner, Department of Chemistry, University of Kentucky.

Saturday, 8 November

9:30 Synthesis of potentially biologically active compounds based on the ministeroid ring structure. John F. Bauer and Walter T. Smith, Jr., Department of Chemistry, University of Kentucky.

9:45 Addition of benzylsodium to carbonyl group. Walter T. Smith, Jr. and David L. Nickel, Department of Chemistry, University of Kentucky.

10:00 Modification of fibrosarcomas in squamous cell carcinomas of the skin in mice using various mouse tissue extracts. S. L. Smith and Stephen A. Winkle, Department of Chemistry, University of Kentucky.

10:15 Coffee break.

10:30 Shift reagent studies of polyfunctional compounds. W. John Layton and S. L. Smith, Department of Chemistry, University of Kentucky.

10:45 The analysis of lunar glasses by instrumental neutron activation analysis. W. B. Stroube, Jr., M. Z. Ali, and W. D. Ehmann, Department of Chemistry, University of Kentucky.

11:00 Determination of zirconium and hafnium in zircons by instrumental neutron activation analysis. A. N. Garg, Maw-Suen Ma, and W. D. Ehmann, Department of Chemistry, University of Kentucky.

11:15 The analysis of environmental water samples by proton-induced x-ray emission. S. M. Cronch, H. W. Laumer, F. Gabbard, and D. Ehmann, Department of Chemistry, University of Kentucky.

11:30 The Messenheimer Reaction with phosphorus oxybromide. Ellis V. Brown and Jean E. Theiss, Department of Chemistry, University of Kentucky.

GEOGRAPHY

Room 107, Health Sciences Building
Dennis L. Spetz, Chairman, Presiding
Wilford A. Bladen, Secretary

Saturday, 8 November

9:30 The rise and fall of Berlin as a world city. Louis Seig, University of Louisville.

9:50 The Ph D migration field of Kentucky. A. William Dakan, University of Louisville.

10:10 Registered voters—a surrogate lot population change in small areas. Thomas Field, University of Kentucky.

10:30 Residential desirability of states: differential perspectives of black and white Kentucky college students. Phil Phillips and Dinker Patel, University of Kentucky.

10:50 An index of highway traffic flow and population for Kentucky's suburban county seats of 1970. William A. Withington, University of Kentucky.

11:10 Sectional business meeting, election of officers, and other matters.

GEOLOGY

Randy Keller, Chairman
Charles T. Helfrich, Secretary
Division A: Charles T. Helfrich, Presiding
Room 201, Health Sciences Building
Stratigraphy and Sedimentation

Friday, 7 November

1:00 Observations of chert "dikes" in the Upper Newman of Menifee County, Kentucky. H. P. Hoge, Department of Geology, Eastern Kentucky University.

1:15 Mineralogic variation as a chronologic tool. Archie H. Martin, III, (sponsored by D. C. Haney), Department of Geology, Eastern Kentucky University.

1:30 The Boyle–Duffin Contact across the Cincinnati Arch. J. E. Conkin, Department of Geology, University of Louisville, and B. M. Conkin, Jefferson Community College.

1:45 Evidence supporting the Mississippian–Pennsylvanian unconformity in eastern Kentucky. D. C. Haney and N. C. Hester, Department of Geology, Eastern Kentucky University.

2:00 Characterization of lithologic units with a matrix of trace element determination. S. L. Elizalde, L. Hin Chyi, G. E. Smith, and W. D. Ehmann (sponsored by W. H. Dennen), Department of Geology, University of Kentucky.

2:15 Conodont paleoecology of the Renfro Member of the Borden Formation and the Newman Limestone of eastern Kentucky. George T. Slone and Perry B. Wigley, Department of Geology, Eastern Kentucky University.

2:30 Break.

3:00 Pulsatory sedimentation in the Lower Pennsylvanian of Menifee County, Kentucky. N. C. Hester, Department of Geology, Eastern Kentucky University.

3:15 The Otter Creek coral bed: a sedimentary environment reconstruction. Alex Papp (sponsored by H. P. Hoge), Department of Geology, Eastern Kentucky University.

3:30 The occurrence of *Stromatactis* in the Louisville Limestone, Jefferson County, Kentucky. G. Kuhnhenn, Department of Geology, University of Louisville.

3:45 *Palaeacis cuneformis* Haime in Milne-Edwards, 1957, emended; its morphology, ontogeny, and stratigraphic significance. J. E. Conkin and T. Bratcher, Department of Geology, University of Louisville.

Division B: Randy Keller, Presiding
Room 305, Health Sciences Center
Potpourii

Friday, 7 November

1:00 Geology and geochemistry of bauxite deposits in the Lower Amazon Basin. William H. Dennen, Department of Geology, University of Kentucky.

1:15 Gravity and tectonic study of the Rome Trough. M. L. Ammerman and G. R. Keller, Department of Geology, University of Kentucky.

1:30 Hill slope processes in southwestern Arizona. Steven A. Cordiviola, Kentucky Geological Survey.

1:45 Dolomitization of Jeptha Knob breccias. C. Ronald Seeger, Department of Geography and Geology, Western Kentucky University.

2:00 Air pollution of Jefferson County. G. H. Hunt, Department of Geology, University of Louisville.

2:15 Evidence for laminar flow during deposition of ash-flow tuff. E. G. Deal (sponsored by H. P. Hoge), Department of Geology Eastern Kentucky University.
2:30 Break.
3:00 A crustal structure study of Kentucky. H. E. Adams and G. R. Keller, Department of Geology, University of Kentucky.
3:15 Strip mine drainage pollution under slightly alkaline conditions. Samuel S. Leung (sponsored by D. C. Haney), Department of Geology, Eastern Kentucky University.
3:30 Environmental and economic interpretations of the McNairy Formation of extreme southern Illinois. David E. Johnson (sponsored by P. B. Wigley), Department of Geology, Eastern Kentucky University.
3:45 The CO_2 and SO_2 reaction with calcareous materials in concentrated dynamic atmospheres. K. L. Gauri, A. Miller, and M. V. Appa Rao, Department of Geology, University of Louisville.

Saturday, 8 November

9:15 Sectional Meeting.
9:30 Tasmanian Permian Foramenifera. B. M. Conkin, Jefferson Community College, and J. E. Conkin, Department of Geology, University of Louisville.
9:45 Deformation along the Kentucky River Fault Zone near Boonesboro and Camp Nelson, Kentucky. Donald T. Phillips II, and Archie H. Martin III (sponsored by D. C. Haney), Department of Geology, Eastern Kentucky University.
10:00 Distribution and origin of Mississippian geodes and geodal minerals in Kentucky. Irving S. Fisher, Department of Geology, University of Kentucky.
10:15 A tectonic, aeromagnetic, and gravity study of a portion of central Kentucky. D. F. B. Black, USGS, Lexington, R. W. Johnson, TVA, Knoxville, Tennessee, and G. R. Keller, Department of Geology, University of Kentucky.
10:30 Plant spores as a tool in carboniferous stratigraphic problems in eastern Kentucky. C. T. Helfrich, Department of Geology, Eastern Kentucky University.
10:45 Break.
11:00 Textural analysis of a point bar–fan delta? complex on the Red River. R. E. Sergeant, Department of Geology, Eastern Kentucky University and Kentucky Geological Survey, and George T. Slone, United States Army.
11:15 Palynology of clastics in the lower tongue of the Breathitt Formation (Lower Pennsylvanian). Jane Sasso (sponsored by C. T. Helfrich), Department of Geology, Eastern Kentucky University.
11:30 Petrology of an upper Mississippian carbonate unit in eastern Kentucky. Doug Dillenberger (sponsored by H. P. Hoge), Department of Geology, Eastern Kentucky University.
11:45 Correlation of ambient and accelerated deterioration of natural building stone. K. L. Gauri and M. V. Appa Rao, Department of Geology, University of Louisville.

PHYSICS

Room 205, Health Sciences Building
William E. Maddox, Chairman, Presiding
Charles D. Teague, Secretary

Friday, 7 November

2:00 KAPT Business Meeting, William E. Maddox, President, Presiding.
2:30 Nova Cygni 1975—observations of a new star in the constellation Cygnus. Karen Hackney, R. L. Hackney, D. H. Yeager, Western Kentucky University, J. P. Oliver, R. L. Scott, A. G. Smith, R. J. Leacock, D. R. Florkowski, W. H. Schneider, Rosemary Hill Observatory, University of Florida.
2:40 Observations of eclipsing variable stars and their possible flare activity. Thomas Faller and Al Fennelly, Western Kentucky University.
2:50 Stability of the ground state of the H_{12} system. W. T. Kwo, University of Louisville.
3:00 Bone structure and regeneration: a biophysical hypothesis. Adrian Gooch, Deborah Morgan, Richard Buchannan, Michael Clagett, Richard Graham, Phillip Drake, Paul Graham, Joseph Roberts, and Al Fennelly, Western Kentucky University.
3:10 Autoionization in Tl^{204}, Tc^{99}, Pm^{147}. C. E. Laird and Parl C. Hummel, Eastern Kentucky University.
3:20 Two-photon ionization of cesium. J. E. Parks, Western Kentucky University, R. N. Compton, Oak Ridge National Laboratory, and W. F. Frey, Davidson College.
3:30 Energy requirements for creation of an artificial lunar or martian oxygen bearing atmosphere. Paul Davis and Al Fennelly, Western Kentucky University.

Saturday, 8 November

10:00 The acoustics of brass instruments. Dr. Ben Gossick, University of Kentucky. (Invited paper.)
10:30 STATZ—Computerized statistics for the non programer. S. J. Zeil, Thomas More College.
10:40 PHYMOD Consortium—A cooperative effort in modular physics instruction. Frank Six, Western Kentucky University.
10:50 Crystal orientation studies of the Mossbauer effect in Ferrocene. A. L. Stacy and D. J. Boyle, Thomas More College.

11:00 The crystal field in $SrF_2:Gd^{3+}$, Yb^{3+}. R. L. Smith and G. K. Miner, Thomas More College.
11:10 The detection of intersteller ethyl alcohol. Frank O. Clark, University of Kentucky.
11:20 New measurements of the diamagnetic susceptibilities of biphenyl. P. L. Foltz and J. E. Lang, Thomas More College.
11:30 ACT scores as predicators of performance in a college physics program. D. J. Boyle and G. K. Miner, Thomas More College.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY

Room 101, Health Sciences Building
James L. Voogt, Chairman, Presiding
Sanford L. Jones, Secretary

Friday, 7 November

2:00 Changes in selected autonomic functions associated with dental stress. Gregory A. West and Kenneth H. Reid, Department of Physiology and Biophysics, University of Louisville Health Sciences Center.
2:15 Electrical activity in isolated rat lung. Edward J. Radin and Joseph Engelberg, Department of Physiology and Biophysics, University of Kentucky Medical Center.
2:30 Progesterone levels in ovaries of *Desmognathus fuscus fuscus* during the breeding and nonbreeding seasons in response to human chorionic gonadotropin. Sanford L. Jones, Department of Biological Sciences, Eastern Kentucky University.
2:45 Sympathetic control of carotid body response to hypoxia. Michael T. Sewell and John R. Meyer, Department of Physiology and Biophysics, University of Louisville Health Sciences Center.
3:00 Influence of cold torpor and state of hydration on kidney acid mucopolysaccharides in emydid turtles. Charles E. Kupchella, Cancer Research Center, University of Louisville Health Sciences Center.
3:15 Hormonal control of pseudopregnancy. Bach-Tuyet Dang and James L. Voogt, Department of Physiology and Biophysics, University of Louisville Health Sciences Center.
3:30 Ventilatory response in chemically sympathectomized rats. Catherine A. Sharp and John R. Meyer, Department of Physiology and Biophysics, University of Louisville Health Sciences Center.
3:45 Sectional business meeting and election of officers.

Saturday, 8 November

10:00 Reflexive and behaviorial responses of cats to tooth pulp stimulation over time. Stephen J. Wilson and Kenneth A. Reid, Department of Physiology and Biophysics, University of Louisville Health Sciences Center.
10:15 Electrophoretic patterns of esterase and lactic dehydrogenase isozymes and total protein during the estrous cycle, pseudopregnancy, and steroid treatment. Shun Yee Au and Sanford L. Jones, Department of Biological Sciences, Eastern Kentucky University.
10:30 Effects of delta-9-tetrahydrocannabinol on *Tetrahymena pyriformis* GL. J. T. Summersgill, R. E. Daniel, L. Muma, and D. O. Abbott.
10:45 A phylogenetic study of the family Cyprinidae based on electrophoretic patterns of esterase and lactic dehydrogenase isozymes and total protein. David L. Swafford, Sanford L. Jones, and Branley A. Branson, Department of Biological Sciences, Eastern Kentucky University.
11:00 L-DOPA as an inhibitor of prolactin in steroid treated ovariectomized rats. Agnes Jiminez, L. A. Carr, and James L. Voogt, Department of Physiology and Biophysics, University of Louisville Health Sciences Center.
11:15 Ultraviolet exposure effects on mammalian virus cell capacity. Thomas P. Coohill and Stephanie Drake, Department of Biophysics, Western Kentucky University.

SCIENCE EDUCATION

Room 103, Dental School Building
J. Truman Stevens, Chairperson, Presiding
Ron Atwood, Secretary

Saturday, 8 November

9:40 Overview of the new state program of studies in science. Frank B. Howard, Science Consultant, State Department of Education.
10:00 A report of the KAPS elementary science needs survey. Ann Hoffelder, Department of Chemistry, Cumberland College.
10:20 Effect of retesting in a competency based teacher education component. Ron Atwood, University of Kentucky.
10:40 Relationships among student interest, process skills, and cognitive preferences for junior high science. J. Truman Stevens, University of Kentucky.
11:00 Sectional Business Meeting.

PSYCHOLOGY

Room 106, Health Sciences Building
Francis H. Osborne, Chairperson, Presiding
Brent C. White, Secretary

Saturday, 8 November

9:30 Accurate preparatory information, cognitive strategies, and reactions to noxious stimuli.

D. H. Brown and B. Greene, Psychology Program, Centre College of Kentucky.

9:45 The parallel processing model and reactions to emotion producing stimuli. A. Britton and D. H. Brown, Psychology Program, Centre College of Kentucky.

10:00 Two faces of religious conservatism. R. D. Kahoe, Department of Psychology, Georgetown College.

10:15 Attenuation of amphetamine induced arousal in caffeine tolerant rats. B. C. White and K. Haswell, Psychology Program, Centre College of Kentucky.

10:30 Effects of p-chlorophenylalanine and alpha-methyl-p-tyrosine pretreatment of caffeine induced activity. C. Clegg and B. C. White, Psychobiology Program, Centre College of Kentucky.

10:45 Business meeting and election of officers.

SOCIOLOGY

Room 124, Dental Science Building
James S. Wittman, Jr., Chairman, Presiding
Craig H. Taylor, Secretary

Friday, 7 November

1:00 Kentucky high school students' beliefs concerning their maturity for marriage. James S. Wittman, Jr., Western Kentucky University.

1:25 The high school community survey an untapped community resource. Robert L. Hoffelder, Cumberland College and Jo Florence Cordell, Williamsburg High School.

2:00 Lecture demonstration: the use of sociological games in the teaching of sociology. Paul R. Wozniak, Western Kentucky University.

Saturday, 8 November

9:30 Panel Discussion: The role of graduate programs in Kentucky's regional state universities. Discussants: To be announced.

ZOOLOGY

Room 11-D, Dental School Building
J. G. Rodriguez, Chairman, Presiding
Henry H. Howell, Secretary

Friday, 7 November

1:00 Election of Zoology Section officers after report of the nominating committee and floor nomination; other business.

1:15 Population studies of phytophagous and predaceous arthropods in soybeans. K. V. Yeargan, Department of Entomology, University of Kentucky.

1:30 Effect of temperature on photoperiodic induction of diapause in *Manduca sexta*. Richard Thruston, Department of Entomology, University of Kentucky.

1:45 Dryinid parasitoids of leafhoppers. David W. Back and Paul H. Freytag, Department of Entomology, University of Kentucky.

2:00 Coniopterygidae of Kentucky. Victor Johnson and Paul H. Freytag. Department of Entomology, University of Kentucky.

2:15 Behavior of mites towards essential oil mixtures from strawberry foliage. J. G. Rodriguez, Department of Entomology, University of Kentucky.

2:30 Survivorship in *Drosophila melanogaster* populations exposed to abnormal oxygen concentrations. Gerrit Kloek, Department of Biology, Kentucky State University.

2:45 Gene frequently changes in *Drosophila melanogaster* populations exposed to ab-abnormal oxygen concentrations. Dennis Ralin, Department of Biology, Kentucky University.

3:00 Histological changes in *Drosophila melanogaster* exposed to abnormal oxygen concentrations. Terry Kelley, Department of Biology, Kentucky State University.

3:15 A second year of an ecological study on the water willow (*Justicia americana*) patches in Jessamine Creek. Henry H. Howell, Department of Biology, Asbury College.

3:30 Combinations of sexes of children: a factor in population control. Elmer Gray and Deborah K. Morgan, Department of Agriculture, Western Kentucky University.

3:45 Seasonal molt in *Permyscus leucopus* in and around Louisville Kentucky. Barbara Lensing, University of Louisville.

Saturday, 8 November

9:40 Breeding behavior of *Notropis ardens*. Doris Westerman, Department of Zoology, University of Kentucky.

10:00 A new technique in pitfall trapping. Burt Smith, Department of Biology, Western Kentucky University.

10:20 Distribution, including new state records, of fishflies in Kentucky (Megaloptera: Corydalidae). Donald C. Tarter, William D. Watkins, and Michael L. Little, Department of Biological Sciences, Marshall University, Huntington, West Virginia.

10:40 The mosquitoes of Jefferson County, Kentucky: a ten-year analysis. Charles V. Covell, Jr., Department of Biology, University of Louisville.

11:10 A preliminary report on Collembola and other soil arthropods in Bernheim Forest, Kentucky. Jack S. Lesshafft, Department of Biology, University of Louisville.

11:30 A report of moths collected at a single station in southwestern Jefferson County, Kentucky. Alan J. Brownell, Department of Biology, University of Louisville.

KENTUCKY ACADEMY OF SCIENCE
1975–1976 Sectional Officers

Anthropology
Richard Levy (Chm)
Department of Anthropology
University of Kentucky
Lexington, KY 40506

Michael B. Collins (Secy)
Department of Anthropology
University of Kentucky
Lexington, KY 40506

Botany and Microbiology
Harold E. Eversmeyer (Chm)
Department of Biology
Murray State University
Murray, KY 42072

Joe E. Winstead (Secy)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101

Chemistry
William R. Oliver (Chm)
Department of Chemistry
Northern Kentucky State College
Highland Heights, KY 41076

Ilyas Ahmad (Secy)
Department of Chemistry
Kentucky State University
Frankfort, KY 40601

Geography
Phillip Phillips (Chm)
Department of Geography
University of Kentucky
Lexington, KY 40506

W. A. Franklin (Secy)
Department of Geography
Murray State University
Murray, KY 42072

Geology
Charles T. Helfrich (Chm)
Department of Geology
Eastern Kentucky University
Richmond, KY 40475

Garry L. Kuhnhenn (Secy)
Department of Geology
University of Louisville
Louisville, KY 40208

Physiology, Biophysics, Pharmacology
Sanford L. Jones (Chm)
Biology Department
Eastern Kentucky University
Richmond, KY 40475

Thomas P. Coohill (Secy)
Department of Biology–Physics
Western Kentucky University
Bowling Green, KY 42101

Science Education
Ronald K. Atwood (Chm)
Taylor Educational Building
University of Kentucky
Lexington, KY 40506

J. Truman Stevens (Secy)
Department of Curriculum and Instruction
University of Kentucky
Lexington, KY 40506

Sociology
Robert L. Hoffelder (Chm)
Department of Sociology
Cumberland College
Williamsburg, KY 40769

James S. Wittman, Jr. (Secy)
Department of Sociology & Anthropology
Western Kentucky University
Bowling Green, KY 42101

Psychology
Brent C. White, (Chm)
Department of Psychology
Centre College of Kentucky
Danville, KY 40422

Donald H. Brown (Secy)
Department of Psychology
Centre College of Kentucky
Danville, KY 40422

Zoology
Charles V. Covell, Jr. (Chm)
Department of Biology
University of Louisville
Louisville, KY 40208

Henry H. Howell (Secy)
Biology Department
Asbury College
Wilmore, KY 40390

NEWS AND COMMENT

President's Remarks For the last few years the Kentucky Academy of Science has been looking into itself to determine how it can best meet the needs of the scientific community of this state. From this self-assessment has come several positive steps designed to further advance the effectiveness of the Academy.

One of the major changes has been the revitalization of the Board of Directors to include members of the industrial community. It also has sought to define its role and this has culminated in an initial step with the constitutional changes proposed and passed today. A second change has been in the enlargement of the *Transactions* of the Academy and the upgrading of the quality of papers. It now can serve as a major forum for exchange of ideas for Kentucky scientists and science teachers, if only persons would use it.

A third change has been in the establishment of a plenary session at the annual meeting on topics of vital concern to the Academy. Last year was a forum on the results and implication of a science manpower study for Kentucky, undertaken by Western Kentucky University with only slight involvement by the Academy. This year, yesterday's session on the topic of research in Kentucky proved to be a very lively and involving one. The worth of the plenary session now is self evident.

Last year the Academy became the recipient of an ongoing Floristic Grant, given by an anonymous donor. Within the year, according to recent word, we should be receiving another ongoing grant, this one for botanical or possibly zoological research. Things seem to be picking up for what has been described as a very lethargic and passive academy of science.

But where do we go from here? I think most will agree that we are moving out of thinking of the Academy as a self-serving and second-rate imitation of the larger and more prestigious regional and national discipline conventions. Let us face it, some of our collegues view presenting papers here as second-rate at best! What then does the Academy have to offer the scientific teaching and research community of Kentucky? Have the maligners thrown out the baby with the bath water? Certainly it can serve to communicate, educate, and coordinate scientific information pertinent to this state, if nothing else. This, in and of itself is a major and important function. But this requires more than just a gathering together to share in-group papers.

In talking with many members of the Academy, I come away with the conclusion that this body is now ready for more. We have been shaken to the roots by two major impacts. The first relates directly to the Kentucky science manpower study which shows how minimal is the return of federal research and development monies to Kentucky's institutions and scientists, relative to what we are taxed. We rank on the abysmal bottom when compared with our sister states!

The second event is related to our state's very poor allocations of funds for public education, especially at the subcollegiate level. The already in effect pupil weighting formula for allocating state educational funds will wipe out in a very short while any possibility of quality science education in this state. Then where will the providers of scientific and technological expertise come from in 5 years, 10 years, 20 years, and on? Will they continually have to be imported from other states as has been this state's past history? Presently we are fighting a rear guard action as exemplified by the proposal offered a few moments ago by Dr. George. We are attempting to recoup a very serious loss. In part, we as an Academy had it coming due to lack of activity and involvement in the public science education issues. The age of innocence for science is gone. No longer can we in this particular body remain aloof from the public and political issues. Many other state and national science bodies have known this for quite some time. If we do not become involved in the issues, then science and

science education in Kentucky will be dead because it will appear as irrelevant in the course of this state's affairs.

We have offered the services of this Academy "... to provide advisory services to State and local Governments in the areas of Science and Technology," as is stated in our publicity brochure. But this is passive! Who or what agencies have bothered to call upon us in any major way? How is anyone in state government to know that we are capable of solving scientific problems or that any science related problems exist if we do not inform anyone in Frankfort?

The members of this Academy are together one of the greatest resources for information that a state legislative or executive body could wish for. We have the personpower and intellectual ability to provide the necessary information for responsible and meaningful decision making in scientific matters.

In an attempt to rectify some of the lack of public involvement by the Academy into scientific issues and matters important for the people of this state I will establish immediately, two *ad hoc* committees. This is done with the encouragement of the Executive Board of the Academy including some Board of Directors members. If over the year these two *ad hoc* committees develop as hoped, then I will prepare to offer to the Academy a year from now resolutions to amend its constitution to include these committees as permanent standing committees.

The first *ad hoc* committee to be established is the Public Science Education Committee. Dr. Ted George has kindly consented to serve as its chairman. Other members will be the President of the Academy, a second collegiate level science teacher, and two subcollegiate science teachers, with the Vice President of the Academy as an *ex officio* member. The purpose of this committee will be to review pending legislation and directives pertaining to public science education in the state. It will recommend to the Legislative Committee of the Academy actions to be taken on behalf of the Academy to endorse and to support the advancement of science in Kentucky public education.

The second committee to be established is the State Government Science Advisory Committee. Its membership will include the President of the Academy, a member of the Board of Directors, a collegiate level science department chairman or above (such as a dean), two members at large from the Academy, the Past President of the Academy, with the President Elect as an *ex officio* member, for a total of six full members.

The purpose of this committee is to bring to the attention of the Governor and the members of the Legislature issues and concerns pertinent to the state scientific community and of particular significance for the state of Kentucky. First of all, I will notify the Governor and certain members of the Legislature of the existence of this committee, and of the willingness of the Academy to aid in their considerations of scientific matters. At appropriate times and under appropriate situations this committee will inform these persons.

As a body, I think it is fair to say that we are quite politically naive. And so this latter committee's initial progress will be slow as we learn our way. We can use all of the help available, for there are few among us who are aware of the necessary political procedures. I have asked Dr. Marvin Russell to be on this committee. I hope that his very busy schedule will permit him to say yes.

To the end of advancing the Academy and of science and science education in Kentucky, I offer these comments and proposals. Hopefully you will have listened and will help. Are there any comments? Do I have any volunteers? Thank you.

Frederick M. Brown

Tech Aqua Summer Program The Tech Aqua Biological Field Station has announced the courses to be offered during the two five-week summer terms (6 June–10 July; and 14 July–18 August) in 1976. The courses are Local Flora, Freshwater Algae, Freshwater Invertebrates, Ornithology, and Mycology for the first term. Second term courses will be Ecosystem Analysis, Ichthyology, Limnology, Aquatic Microbiology, and Biology of the Chironomids. The Tech Aqua program is conducted by a consortium composed of Tennessee Tech, Middle Tennessee, Belmont, Tennessee State, Trevecca, Sewanee, Univ. of Tennessee-Martin, Vanderbilt, and Western Kentucky University. The field station, a modern campus of 18 air-conditioned buildings, is located on Center Hill Reservoir approximately 60 miles east of Nashville, Tennessee. For information contact Dr. Robert Martin, Dept. of Biology, Tennessee Tech, Cookeville, Tenn. 38501.

The Society of Kentucky Lepidopterists A Society of Kentucky Lepidopterists was formed at a meeting at the University of Louisville in November 1974. Anyone of any age who is interested in Lepidoptera (butterflies and moths) is welcome, even from outside Kentucky. A collecting trip weekend was very successful at Pine Mountain State Park in July 1975, as was the second Annual Meeting at University of Louisville on 22 November. A quarterly newsletter, *Kentucky Lepidopterist*, is the main reason for charging dues of $3 annually for Regular Members, $1.50 for Associate Members (no voting or office holding privileges). A spring field weekend at Natural Bridge State Park and environs is slated for 23–25 April 1976. We welcome new members. Write to Dr. Charles V. Covell Jr., Department of Biology, University of Louisville, Louisville, Kentucky 40208. Make checks payable to the Society of Kentucky Lepidopterists.

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Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

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Structure and Composition of a Climax Forest System in Boone County, Kentucky

Michael E. Held and Joe E. Winstead

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

The structure and composition of a 52-hectare mature mesic hardwood forest in Boone County, Kentucky, were studied during 1973–1974. *Acer saccharum* was the dominant tree, with *Fraxinus americana* as subdominant. In the understory vegetation, *Acer* and *Fraxinus* were among the dominant genera indicating a climax stage of development. A previously cleared area in the forest was also analyzed. The dominant tree species of the canopy were also dominant in the understory in the disturbed area, indicating a return to the stable maple–ash system of the entire forest. During the spring of 1974, tornadoes moved across Boone County and one damaged the forest under study. The effects of this windstorm were included in the collection of data, and damage was not limited to any specific species. There was no apparent relationship between root depth and soil type among uprooted trees.

Introduction

There is a distinct lack of information concerning the forest vegetation of the Commonwealth of Kentucky. Especially lacking are studies of forests before the development and extensive use of the land. Although there is a great amount of general information dealing with the Eastern Deciduous Forest Biome, few studies deal with the composition and structure of climax forests in Kentucky.

A wooded area in Boone County, Kentucky, known as Dinsmore's Woods, was selected for an intensive analysis in 1973, after a preliminary investigation by the authors and others indicated this to be a relict forest. This project was undertaken to describe the structure and composition of the forest vegetation, to analyze the successional pattern in the forest, and to provide a permanent record of Dinsmore's Woods as a foundation for possible future studies of the structural and functional aspects of forests.

Dinsmore's Woods lies 8 km west of Burlington, the county seat of Boone County, Kentucky, and 3.2 km east of the Ohio River. The forest covers an area of 52.6 hectares.

Dinsmore's Woods occupies moderate to steep slopes that lie 218–250 m above sea level and some 60 m above the floodplain in the valley of the Ohio River. The woods is presently owned by Mrs. Martha Breasted. It has been in her family's possession since the 1830's, as evidenced by the grave markers in a small family cemetery by the edge of the forest. The woods is relatively undisturbed; there having been only 3 recorded removals of trees: (1) dead chestnuts were logged after the chestnut blight of the late 1930's; (2) a small area at the top of one slope was cleared for a small garden plot, long since abandoned, is described as the disturbed area; and (3)

the final removal of trees consisted of those damaged by the 3 April 1974 tornado. On that date, a tornado, with winds exceeding 320 km per hour, raked across Boone County. One of the areas damaged was Dinsmore's Woods. That damage and subsequent removal of trees certainly will have a distinct effect on the composition of the forest.

The bedrock of Boone County is primarily Ordovician limestone and shale of Eden, Maysville, and Richmond age (McFarlan 1943). Along with the parent material, Pleistocene glacial deposits, which vary greatly in composition and thickness, mantle the northwestern section of Boone County. It is this region that was covered by the Illinoian glaciation but untouched by later glaciers. These glacial deposits are commonly so weathered that they are difficult to recognize and classify. They are, therefore, considered one unit and are referred to as "till." These till deposits are well covered by a well-leached layer of loess from the Wisconsin age, although the Wisconsin glacier did not reach as far south as Kentucky.

A search of the literature indicates a distinct lack of forest ecosystem analyses in the northern region of Kentucky. A floristic checklist, prepared by Nelson (1918), and the work of Keith (1968) are the only recorded studies of the forest vegetation of Boone County completed before this project was undertaken. It is hoped that this study will contribute to the ever increasing botanical knowledge of the Commonwealth. The lack of such studies was noted by Meijer (1970).

Acknowledgments

We extend appreciation to Drs. Kenneth A. Nicely and Herbert E. Shadowen of Western Kentucky University and to Dr. William S. Bryant of Thomas More College, all of whom aided in the preparation of this manuscript. We are grateful to Mrs. Martha Breasted and her daughter, Sarah, who permitted us to carry out research on their property.

Materials and Methods

The circular plot method (Ohmann 1973) was employed to determine species composition, relative frequency, and relative density of all size classes of vegetation. Relative dominance, based on calculated basal area, was determined for the tree species. At Dinsmore's Woods, 23 circular plots, each of 0.125 ha, were randomly placed throughout the forest.

The diameter breast height (dbh) of each tree species greater than 10 cm was recorded for each circular plot. Saplings less than 10 cm dbh (but greater than 1 m in height) were sampled in a 0.062-ha circular plot placed within each 0.125-ha plot. Seedlings less than 10 cm dbh and less than 1 m in height were counted in an 0.031-ha circular plot inside the 0.062-ha plot. All 3 plots had the same center point. Saplings and seedlings were identified to genus (species if possible). Plant nomenclature follows that of Fernald (1950).

To check the adequacy of sampling at Dinsmore's Woods, a species-area curve was determined for all 3 size classes of vegetation (Oosting 1956). Sampling was considered adequate when a 10 percent increase in area sampled yielded additional species equal to only 5 percent of the total number present. That point is equal to the minimum number of circular plots which should be used to obtain an adequate sample of the vegetation.

Within the boundaries of the forest stand, 3 sets of data were analyzed. Separate determinations were made for the vegetational composition of the disturbed area and the tornado damaged trees. The data from those 2 sets were also included with data analyzed from samples taken to represent the entire forest. Relative density, relative frequency, and relative dominance were calculated and summed to give importance values for each tree species (Curtis and McIntosh 1951). Relative density and relative frequency were determined for the saplings and seedlings of the forest area sampled. The same calculations were performed for the data of the disturbed area.

TABLE 1.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), AND IMPORTANCE VALUE (IV) OF ALL TREE SPECIES OVER 10 CM DBH AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV
Acer saccharum	65	.3571	.3443	.2180	.9194
Fraxinus americana	26	.1428	.1570	.1450	.4448
Quercus alba	7	.0384	.0733	.0670	.1787
Q. rubra	2	.0109	.0432	.0240	.0781
Q. muehlenbergii	2	.0109	.0189	.0240	.0538
Q. prinus	1	.0054	.0034	.0120	.0208
Celtis occidentalis	20	.1098	.0930	.0960	.2988
Ulmus rubra	18	.0989	.0464	.0840	.2293
Gleditsia triacanthos	9	.0464	.0309	.0490	.1293
Carya cordiformis	5	.0274	.0474	.0490	.1238
Ostrya virginiana	6	.0329	.0060	.0490	.0879
Fagus grandifolia	2	.0109	.0342	.0240	.0691
Cercis canadensis	4	.0219	.0181	.0240	.0640
Juglans nigra	4	.0219	.0139	.0240	.0598
Acer negundo	4	.0219	.0099	.0240	.0558
Tilia americana	1	.0054	.0343	.0120	.0517
Robinia pseudo-acacia	2	.0109	.0070	.0240	.0419
Maclura pomifera	1	.0054	.0124	.0120	.0298
Prunus serotina	1	.0054	.0041	.0120	.0215
Cornus florida	1	.0054	.0007	.0120	.0181
Aesculus glabra	1	.0054	.0005	.0120	.0179
Totals	182	.9954	.9989	.9970	2.994

For the tornado damaged trees within any plot, the relative density, relative frequency, and relative dominance were calculated and summed to give importance values. The length of each tree was determined and the extent of the rooting system was measured in all windthrown trees.

During the period of research, a lumber company was employed by the owner to clear the woods of all fallen and tornado damaged trees. Stumps left from that work provided a record of annual growth rings. A random sample of 10 stumps was analyzed to give an approximation of the age of the stand.

Soil samples from a depth of 5 cm were obtained from each circular plot in Dinsmore's Woods. A LaMotte Soil Test Kit was used to measure soil pH. Soil texture was analyzed by the hydrometer method of Bouyoucos (1936).

RESULTS

Species-area curves for the tree class of vegetation, saplings, and seedlings demonstrated that in all size classes of vegetation analyzed, the number of circular plots utilized was more than adequate. Although 23 plots were used for the tree class, 5 plots of 0.125 ha were shown to be the minimum number needed to characterize that class. In the sapling and seedling classes, 23 plots (0.062 ha and 0.031 ha, respectively) were used, whereas for the sapling class, 3 plots were considered adequate, and for the seedling size range, 2 plots was the minimum needed.

In Dinsmore's Woods, 21 tree species were identified in the forest and are ranked according to their importance values in Table 1. Of the 4 predominant tree species, *Acer saccharum* had a greater relative density, relative dominance, and relative fre-

TABLE 2.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), AND RELATIVE DENSITY PLUS RELATIVE FREQUENCY VALUE (RD + RF), FOR THE SAPLINGS OF DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Genera	N	RD	RF	RD + RF
Acer saccharum	129	.2841	.2015	.4856
Ulmus rubra	111	.2444	.1472	.3916
Asimina triloba	63	.1387	.0697	.2084
Fraxinus americana	36	.0792	.1162	.1954
Celtis occidentalis	28	.0616	.0697	.1313
Lindera benzoin	17	.0374	.0620	.0994
Carya sp.	13	.0286	.0697	.0983
Quercus spp.	11	.0242	.0620	.0862
Prunus serotina	16	.0352	.0465	.0817
Ostrya virginiana	8	.0176	.0387	.0563
Cornus florida	7	.0154	.0310	.0464
Morus rubra	5	.0110	.0155	.0265
Cercis canadensis	3	.0066	.0155	.0221
Tilia americana	2	.0044	.0155	.0199
Fagus grandifolia	1	.0022	.0077	.0099
Robinia pseudo-acacia	1	.0022	.0077	.0099
Sassafras alibidum	1	.0022	.0077	.0099
Euonymus americanus	1	.0022	.0077	.0099
Liriodendron tulipifera	1	.0022	.0077	.0099
Totals	454	.9994	.9992	1.9986

TABLE 3.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), AND THE RELATIVE DENSITY PLUS RELATIVE FREQUENCY VALUE (RD + RF), FOR THE SEEDLINGS OF DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Genera	N	RD	RF	RD + RF
Acer spp.	336	.3532	.1863	.5395
Ulmus rubra	210	.2208	.1304	.3512
Fraxinus spp.	120	.1261	.1180	.2441
Prunus serotina	46	.0483	.0745	.1228
Carya sp.	37	.0389	.0745	.1134
Lindera benzoin	53	.0557	.0559	.1116
Celtis occidentalis	36	.0378	.0683	.1061
Asimina triloba	38	.0399	.0496	.0895
Quercus spp.	26	.0273	.0621	.0894
Gleditsia triacanthos	18	.0189	.0310	.0499
Sassafras albidum	12	.0115	.0310	.0425
Cornus florida	4	.0042	.0248	.0290
Ostrya virginiana	6	.0063	.0186	.0249
Tilia americana	3	.0030	.0186	.0216
Cercis canadensis	2	.0021	.0124	.0145
Fagus grandifolia	2	.0021	.0062	.0083
Juglans sp.	1	.0010	.0062	.0072
Morus rubra	1	.0010	.0062	.0072
Totals	951	.9981	.9746	1.9727

quency than any other tree. It must be noted that by combining the 4 species of *Quercus*, a collective importance value of .3314 was obtained even though no single oak species had an importance value higher than .1787.

A total of 1,585 woody individuals in the 3 size classes was recorded at Dinsmore's Woods. This corresponds to a density of 566 stems per hectare. In the tree size class, there were 182 individuals, a density of 65 trees/ha. The trees had a mean diameter of 32 cm and a total basal area of 28.1 m^2/ha.

When the saplings were ranked according to relative density plus relative frequency (Table 2), the 5 most important genera were *Acer*, *Ulmus*, *Asimina*, *Fraxinus*, and *Celtis*. When relative density plus relative frequency (Table 3) were determined for the seedlings of the entire forest at Dinsmore's Woods, the top 5 genera were *Acer*, *Ulmus*, *Fraxinus*, *Prunus*, and *Carya*. Since it is extremely difficult to make positive identifications of saplings and seedlings of such complex genera as *Acer* and *Quercus* and others, no attempt was made to differentiate between species of several taxa. Thus, in tabulating and discussing the data above and elsewhere, all individuals of several genera are treated collectively.

The 5 important genera in all 3 size classes in the complete forest are compared in Table 4. There were 3 dominant genera in each size class; *Acer*, ranked first in all size classes, *Ulmus*, and *Fraxinus*. *Celtis* was an important genus in the tree and sapling classes.

In the disturbed area of Dinsmore's Woods, 10 tree species were recorded in an area of 4 circular plots and were included in the analysis of the complete forest. The tree species of the disturbed area are ranked according to their importance values in Table 5, where the 5 predominant species were: *Celtis occidentalis*, *Juglans nigra*, *Ulmus rubra*, *Fraxinus americana*, and *Cercis canadensis*.

TABLE 4.—COMPARISON OF THE 5 DOMINANT TREE SPECIES, SAPLING, AND SEEDLING GENERA, WITH THEIR IMPORTANCE OR RELATIVE DENSITY PLUS RELATIVE FREQUENCY VALUES, AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Tree	IV	Sapling	RD + RF	Seedling	RD + RF
Acer saccharum	.9194	*Acer saccharum*	.4856	*Acer* spp.	.5395
Fraxinus americana	.4448	*Ulmus rubra*	.3916	*Ulmus rubra*	.3512
Quercus spp.	.3314	*Asimina triloba*	.2084	*Fraxinus americana*	.2241
Celtis occidentalis	.2988	*Fraxinus americana*	.1954	*Prunus serotina*	.1228
Ulmus rubra	.2293	*Celtis occidentalis*	.1313	*Carya* sp.	.1134

Among saplings of the disturbed area, listed according to their relative density plus relative frequency values in Table 6, the 5 leading genera were *Ulmus*, *Acer*, *Celtis*, *Fraxinus*, and *Prunus*. In the seedling size class of the disturbed area (Table 7), the 5 dominant genera, ranked according to their relative density plus relative frequency values, were *Fraxinus*, *Acer*, *Prunus*, *Celtis*, and *Gleditsia*.

The leading individuals of the disturbed area in all 3 vegetational size classes are compared in Table 8. *Celtis* and *Fraxinus* occurred in all 3 classes, and *Acer*, *Prunus*, and *Ulmus* were found in 2.

Comparison of Tables 4 and 8 shows that *Fraxinus* was the dominant genus in all 6 size classes of both the complete forest and the disturbed area. *Acer*, *Ulmus*, and *Celtis* occurred as leading genera in 5 size classes.

In the tornado damaged area, 12 tree species occurred in 5 circular plots. Of those, 7 were damaged to some extent by the high winds. All trees of the tornado area and their importance values are presented in Table 9, and the 5 leading species were *Acer saccharum*, *Ulmus rubra*, *Celtis occidentalis*, *Tilia americana*, and *Fagus grandifolia*. The trees damaged by the tornado and their importance values are listed in Table 10. The 5 leading species were *Acer saccharum*, *Fraxinus americana*, *Cercis canadensis*, *Celtis occidentalis*, and *Tilia americana*. Only 3 dominant species of all trees in the damaged area were represented among the important damaged trees, *Acer saccharum*, *Celtis occidentalis*, and *Tilia americana*.

The lengths of all trees uprooted were recorded to give an approximation of canopy height. The average height was 20

TABLE 5.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), AND THE IMPORTANCE VALUE (IV) FOR TREES OVER 10 CM DBH IN THE DISTURBED AREA AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV
Celtis occidentalis	12	.3243	.2975	.0714	.6933
Juglans nigra	4	.1081	.1031	.1428	.3541
Ulmus rubra	5	.1351	.0470	.1428	.3250
Fraxinus americana	3	.0810	.1705	.0714	.3230
Cercis canadensis	3	.0810	.1282	.0714	.2807
Gleditsia triacanthos	3	.0810	.0638	.0714	.2163
Acer negundo	3	.0810	.0626	.0714	.2151
A. saccharum	2	.0540	.0159	.1428	.2128
Maclura pomifera	1	.0270	.0924	.0714	.1908
Robinia pseudo-acacia	1	.0270	.0184	.1428	.1883
Totals	37	.9995	.9994	.9996	2.9994

TABLE 6.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), RELATIVE DENSITY PLUS RELATIVE FREQUENCY VALUE (RD + RF), FOR THE SAPLINGS OF THE DISTURBED AREA AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Ulmus rubra	27	.3802	.1500	.5302
Acer saccharum	13	.1830	.2500	.4300
Celtis occidentalis	7	.0985	.1500	.2485
Fraxinus americana	6	.0845	.1000	.1845
Prunus serotina	8	.1126	.0500	.1626
Carya sp.	2	.0281	.1000	.1281
Morus rubra	4	.0563	.0500	.1063
Quercus spp.	2	.0281	.0500	.0781
Robinia pseudo-acacia	1	.0140	.0500	.0640
Lindera benzoin	1	.0140	.0500	.0640
Totals	71	.9993	1.000	1.9993

TABLE 7.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE FREQUENCY (RF), AND RELATIVE DENSITY PLUS RELATIVE FREQUENCY VALUE (RD + RF), FOR THE SEEDLINGS IN THE DISTURBED AREA OF DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Fraxinus americana	33	.3142	.1200	.4342
Acer spp.	14	.1333	.2000	.3333
Prunus serotina	16	.1523	.1200	.2723
Celtis occidentalis	11	.1047	.1200	.2247
Gleditsia triacanthos	14	.1333	.0800	.2133
Ulmus rubra	8	.0761	.1200	.1961
Quercus spp.	2	.0190	.0800	.0990
Carya sp.	2	.0190	.0400	.0590
Fagus grandifolia	2	.0190	.0400	.0590
Lindera benzoin	2	.0190	.0400	.0590
Morus rubra	1	.0095	.0400	.0495
Totals	105	.9994	1.000	1.9994

m, with the tallest being a sugar maple at 34.1 m. The respective average diameters (dbh), and average heights of uprooted trees were *Acer saccharum*, 37.5 cm, 18.5 m; *Ulmus rubra*, 56.6 cm, 19.2 m; *Celtis occidentalis*, 48.8 cm, 26.7 m; *Gleditsia triacanthos*, 15.0 cm, 19.8 m; and *Fraxinus americana*, 35.5 cm, 20.3 m.

Diameters and number of annual rings for 10 trees cut during the clearing operation are listed in Table 11 along with the average diameter and number of rings for each species with 2 or more stumps studied. The largest stump recorded was a *Fraxinus americana* which had a diameter of 76.2 cm and 114 annual rings. These data were helpful in determining the age of the forest community.

The rooting system of all trees uprooted within the sample plots had an average length of 2.3632 m. For individual species, the average lengths were: *Acer saccharum*, 1.9 m; *Gleditsia triacanthos*, 1.7 m; *Fraxinus americana*, 2.3 m; *Celtis occidentalis*, 2.8 m; and *Ulmus rubra*, 3.1 m.

Analysis of the 23 soil samples taken at a depth of 5 cm gave a range in pH of 4.6 to 6.0, with a mean of 5.5. The average soil texture of those samples was 7.2 percent sand, 59.5 percent clay, and 33.3 percent silt. Thirteen samples fell within the clay class and the remaining 10 were silty clay.

DISCUSSION AND CONCLUSIONS

Acer saccharum had the highest relative density, relative frequency, and relative dominance of all tree species recorded at Dinsmore's Woods (Table 1), and *Fraxinus americana* was ranked second in all 3 categories. Different species of *Quercus* did not have individual high importance values, but, collectively were third in decreasing order. Therefore, the forest at Dinsmore's Woods may be classified as a sugar maple system, with white ash and oaks as subdominants. Accessory species were *Celtis occidentalis* and *Ulmus rubra*.

Braun (1916) stated that on more mesophytic slopes near large streams, such as the Ohio River, *Acer saccharum* is the dominant species. Keith (1968), in his analysis of the canopy trees of Boone County, showed that in 5 of 13 forest sample sites, *Acer saccharum* and *Fraxinus americana* were the leading species. The sites analyzed by Keith in 1968 lie approximately 2.4 to 16 km north and somewhat east and west of Dinsmore's Woods.

The dominant species in the tree class, *Acer saccharum* and *Fraxinus americana*,

TABLE 8.—COMPARISON OF THE 5 DOMINANT TREE SPECIES, SAPLING, AND SEEDLING GENERA, WITH THEIR IMPORTANCE OR RELATIVE DENSITY PLUS RELATIVE FREQUENCY VALUES, IN THE DISTURBED AREA, AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Tree	IV	Sapling	RD + RF	Seedling	RD + RF
Celtis occidentalis	.6933	*Ulmus rubra*	.5302	*Fraxinus americana*	.4342
Juglans nigra	.3541	*Acer saccharum*	.4330	*Acer saccharum*	.3333
Ulmus rubra	.3250	*Celtis occidentalis*	.2485	*Prunus serotina*	.2723
Fraxinus americana	.3230	*Fraxinus americana*	.1845	*Celtis occidentalis*	.2247
Cercis canadensis	.2807	*Prunus serotina*	.1626	*Gleditsia triacanthos*	.2133

were present in the 5 important genera of the sapling and seedling classes. This evidence of reproduction of the dominant canopy species in the smaller size classes indicates a stable and climax system.

The various species of *Quercus*, which collectively were present as a leading dominant of the tree class, were not important genera in the sapling and seedling classes of the complete forest. Keever (1973) pointed out that *Quercus alba* in southeastern Pennsylvania is shade intolerant and shows low reproduction. Beals and Cope (1964) stated that in cleared areas of forest in southeastern Indiana, white oak seedlings were shaded out by the fast growing maple saplings and seedlings. Therefore, the dominant oak species in Dinsmore's Woods is not reproducing in great numbers and the combined density of the oak saplings and seedlings is greatly reduced. But some oaks were present in the understory, *Q. rubra*, *Q. muehlenbergii*, and *Q. prinus*, and these species are shade tolerant.

In the sapling class, *Asimina triloba*, and the seedling class, *Prunus* sp. were dominant, but would not be expected to replace the dominant species since they usually are restricted to the understory layer.

In the disturbed area of Dinsmore's Woods, *Celtis occidentalis* was the dominant tree. It possessed the highest density and greatest basal area of all trees recorded in the disturbed area. Accessory species were *Juglans nigra*, *Ulmus rubra*, and *Fraxinus americana*. *Acer saccharum*, the dominant species in the complete forest, ranked among the least important species in the tree class of the disturbed area. How-

TABLE 9.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), AND IMPORTANCE VALUES (IV) OF ALL TREES IN THE TORNADO PLOTS AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV
Acer saccharum	16	.4571	.4128	.2222	1.0921
Ulmus rubra	5	.1428	.0825	.1666	.3919
Celtis occidentalis	3	.0857	.1303	.1111	.3271
Tilia americana	1	.0285	.1325	.0555	.2165
Fagus grandifolia	1	.0285	.1283	.0555	.2123
Quercus rubra	1	.0285	.0386	.0555	.1226
Q. alba	1	.0285	.0040	.0555	.0880
Fraxinus americana	3	.0857	.0121	.0555	.1533
Gleditsia triacanthos	2	.0571	.0131	.0555	.1257
Carya tomentosa	1	.0285	.0363	.0555	.1203
Acer negundo	1	.0285	.0056	.0555	.0896
Cercis canadensis	1	.0285	.0033	.0555	.0873
Totals	36	1.0279	.9994	.9994	3.0267

TABLE 10.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), IMPORTANCE VALUE (IV), AND THE NUMBER UPROOTED (NU) OF SPECIES DAMAGED IN TORNADO PLOTS AT DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV	NU
Acer saccharum	10	.4761	.4404	.3846	1.3011	8
Fraxinus americana	3	.1428	.1263	.2307	.5004	3
Celtis occidentalis	2	.0952	.1177	.0769	.2898	2
Tilia americana	1	.0476	.1554	.0769	.2799	0
Ulmus rubra	1	.0476	.0758	.0769	.2001	1
Cercis canadensis	1	.0476	.0531	.0769	.1776	0
Gleditsia triacanthos	1	.0476	.0057	.0769	.1302	1
Totals	19	.9045	.9744	.9998	2.8791	15

ever, in the comparison between the 3 classes of disturbed area vegetation (Table 8), *Acer* spp. was the second leading dominant in both classes of understory growth. In the sapling class, the 3 dominants, *Ulmus*, *Acer*, *Fraxinus*, of the complete forest were present, and in the seedling class, *Fraxinus* and *Acer* were dominant. These data indicate that although this area was once disturbed, the dominants of the complete forest also were predominant in the understory genera, showing that the disturbed area is returning to the stable system characteristic of the complete forest.

TABLE 11.—ANNUAL RING ANALYSIS FOR 10 RANDOMLY SELECTED STUMPS, DINSMORE'S WOODS, BOONE COUNTY, KENTUCKY

Species	dbh (cm)	Number of rings
Fraxinus americana	76.20	114
F. americana	48.76	91
F. americana	46.99	94
F. americana	41.40	92
F. americana	36.03	77
F. americana	33.02	83
Acer saccharum	46.73	82
A. saccharum	40.64	50
Quercus alba	38.10	96
Prunus serotina	34.79	62

AVERAGE OF STUMP DBH AND NUMBER OF RINGS FOR SPECIES WITH 2 OR MORE STUMPS IN SAMPLE

Species	dbh (cm)	Number of rings
Fraxinus americana	47.06	92
Acer saccharum	43.68	66

A summary of the analysis of tree class vegetation of the tornado damaged plots includes all trees, both damaged and undamaged, in those plots affected by the high winds (Table 9). As in the combined forest, the major important species is *Acer saccharum*. Two other complete forest dominants, *Ulmus rubra* and *Celtis occidentalis*, were important in the disturbed plots, whereas they were dominants in the entire forest community.

In the summary of the data from only the trees damaged by the tornado (Table 10), the leading dominant species damaged was *Acer saccharum*. *Fraxinus americana* was the next important species damaged, and it is to be noted that it was not a leading dominant in the 5 tornado plots, but it was in the complete forest. The opposite situation occurred with *Ulmus rubra*, the second leading dominant in the tornado plots and important in the complete forest, but one of the least dominant trees in the damaged group.

A survey at this site completed by the Kentucky Department for Natural Resources and Environmental Protection, Division of Forestry, during April 1974 (pers. comm.), found 309 damaged trees with dbh's over 25 cm. The predominant species were *Fraxinus americana*, *Juglans nigra*, and *Acer saccharum*.

From the evidence presented here and that of the Division of Forestry survey, it can be concluded that in natural catastrophes, such as high winds, the destructive

force causes damage to all vegetation in the path of the tornado. All species are susceptible to destruction or damage, and the effect caused is haphazard and lacks a logical and orderly pattern.

Root lengths of all species were within 29 percent of the average (2.4 m). Within the path of the tornado, trees were uprooted and damaged, some having a section of the bole broken or bent. In this area, it appears that the effect of the high wind was different on each individual organism, depending on its place in the community, the interrelating topography, and the direction of the tornado path. From root length data, it appears that the depth of penetration by the roots into the soil was not a determining factor in enabling trees to withstand the high velocity and force of the tornado's winds. In Dinsmore's Woods, the average root depth is much greater than the depth in another woods in Pennsylvania struck by a tornado in 1950 (Goodlett 1954). The Pennsylvania study, one of the few known that correlates tornado damage with forest composition, revealed that the average root depth was .80 m.

Analysis of our samples shows that the soil of Dinsmore's Woods is predominantly clay and slightly acidic. This classification disagrees with that of the U.S. Department of Agriculture in their soil survey of Boone County (Weisenberger et al. 1973). That survey described the soil of Dinsmore's Woods, from 0 to 10 cm, as the flaggy silty clay with a pH range near neutral. A possible cause of the differences between that and the present study may be that the government data were based on many samples collected over a large area at preselected points, while our samples were collected randomly over a smaller area. Therefore, any differences probably are due to method of sampling and not method of analysis. Analysis of the plots and soil texture groupings indicates no correlation of species composition with specific soil types and pH range.

As pointed out by Meyer (1953), the

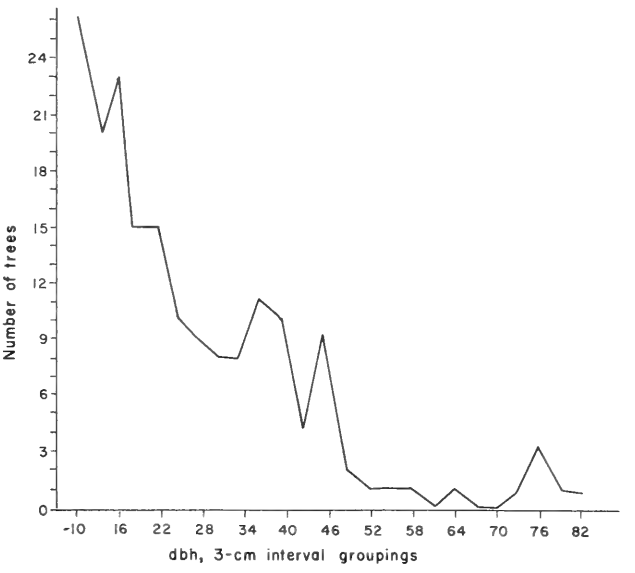


FIG. 1. Distribution of trees from Dinsmore's Woods arranged in 3-cm (7.5-in) diameter groups.

closer the diameter curve approaches the theoretical inverted J curve, the older and more stable the forest system. The curve of Dinsmore's Woods approximates the inverted J curve with some variations (Fig. 1). The bumps in the curve possibly are caused by the inclusion of data of the disturbed area or human error. The greatest number of trees was in the smaller diameter classes, and each increasing size class had, in theory, a smaller number of individuals represented. Usually, after the curve reaches zero in the larger diameter size classes, there is a minor uplift, indicating a few trees present possessing very large diameters.

Most researchers (Braun 1936, 1950; McCoy 1939; Shanks 1953; Beals and Cope 1964) considered the forest of the Illinoian Till Plain to be comprised mainly of beech (*Fagus*), or an association of beech and maple. However, *Acer saccharum* is regarded as the predominant species on more mesophytic slopes of the ravines and valleys that dissect the Till Plain (Braun 1916, 1936, 1950; Beals and Cope 1964).

The forest composition of Dinsmore's Woods is unique when compared with other regions of the state since it is on upland glacial till. Only a small portion

of the state near the Ohio River, between Cincinnati and Louisville, was affected by the Illinoian glacier, whereas the rest of the state is unglaciated. Most of the other forest studies have been on forests of unglaciated regions. Martin (pers. comm.), in his analysis of Lilley Cornett Woods in Letcher County near the Virginia border, found that *Fagus grandifolia* and *Acer rubrum* were the dominant species (Martin and Shepard 1973). The predominance of *Fagus grandifolia* was also noted by Braun in 1942. Braun (1950) classified that as a Mixed Mesophytic Forest. However, in one of the coves of the woods *Acer saccharum* was dominant. That area can be considered more mesic than other sections of Lilley Cornett Woods. Therefore, in the major forest regions of Kentucky, at least in the more mesic regions, *Acer saccharum* is a leading species.

Braun (1950) pointed out that the mesic forests of the glaciated area of Eastern North America are closely related to the mesic forests of the coves and valleys of the southern Appalachians and the Ozarks and that *Acer saccharum* was a dominant species. Curtis (1959) stated that the relatively great floristic homogeneity of the American mesic forests is a rare phenomenon not duplicated by any other major community. He counted both the long geologic history of the areas and the evolution of great shade tolerance of the dominant species as major factors in this homogeneity.

Bougher and Winstead (1974), in their study of a forest in Barren County in south-central Kentucky, showed that the dominant species was *Quercus alba. Acer saccharum* was one of the least important species. The woods, known as Bonayr Forest, is on a level portion of land in the upland of Barren County, and is considered part of the Western Mesophytic Forest, as is Boone County (Braun 1950). Therefore, it is noteworthy that the various forest types that are combined to form the Western Mesophytic Forest lack a single predominant climax type.

LITERATURE CITED

BEALS, E. W., AND J. B. COPE. 1964. Vegetation and soils in an eastern Indiana woods. Ecology 45:777–792.

BOUGHER, C. K., AND J. E. WINSTEAD. 1974. A phytosociological study of a relict hardwood forest in Barren County, Kentucky. Trans. Ky. Acad. Sci. 35:44–54.

BOUYOUCOS, G. J. 1936. Directions for making mechanical analyses of soils by the hydrometer method. Soil Sci. 42:225–229.

BRAUN, E. L. 1916. The physiographic ecology of the Cincinnati Region. Ohio Biol. Surv. Bull. No. 7:116–211.

———. 1936. Forests of the Illinois till plain of Southwestern Ohio. Ecol. Monogr. 6: 89–149.

———. 1942. Forests of the Cumberland Mountains. Ecol. Monogr. 12:413–447.

———. 1950. Deciduous Forests of Eastern North America. Hafner Publ. Co., New York, N.Y. 596 pp. 1972 edition.

CURTIS, J. T. 1959. The vegetation of Wisconsin. Univ. Wis. Press, Madison, Wis. 657 pp.

———, AND R. P. MCINTOSH. 1951. An upland forest continuum in the prairie–forest border region of Wisconsin. Ecology 32:476–496.

FERNALD, M. L. 1950. Gray's Manual of Botany. Eighth edition. Amer. Book Co., New York, N.Y. 1632 pp.

GOODLETT, J. C. 1954. Vegetation adjacent to the border of the Wisconsin Drift in Potter County, Pennsylvania. Harvard Forest Bull. No. 25. 93 pp.

KEEVER, C. 1973. Distribution of major forest species in southeastern Pennsylvania. Ecol. Monogr. 43:303–327.

KEITH, J. R. 1968. Vegetation of the Pleistocene Drift Region, Northern Kentucky. Trans. Ky. Acad. Sci. 29:10–20.

MARTIN, W. H., AND C. SHEPARD. 1973. Trees and shrubs of Lilley Cornett Woods, Letcher County, Kentucky. Castanea 38:327–335.

MCCOY, S. 1939. A phytosociological study of the woody plants constituting 25-type forests of the Illinoian till plain of Indiana. Proc. Ind. Acad. Sci. 48:50–66.

MCFARLAN, A. C. 1943. Geology of Kentucky. Univ. Ky. Press, Lexington, Ky. 531 pp.

MEIJER, W. 1970. The flora and vegetation of Kentucky as a field for research and teaching. Castanea 35:161–176.

MEYER, H. A. 1953. Forest mensuration. Pennsylvania Valley Publ., State College, Pa. 357 pp.

NELSON, J. C. 1918. Plants from Boone County, Kentucky. Proc. Ind. Acad. Sci. 28:125–143.

OHMANN, L. F. 1973. Vegetation data collection in temperate forest research natural areas. USDA For. Serv. Res. Pap. NC-92. 35 pp.

OOSTING, H. J. 1956. The Study of Plant Communities. W. H. Freeman Co., San Francisco, Cal. 440 pp.

SHANKS, R. E. 1953. Forest composition and species association in the beech–maple forest region of western Ohio. Ecology 34:455–466.

WEISENBERGER, B. C., E. W. DOWELL, T. R. LEATHERS, H. B. ODOR, AND A. J. RICHARDSON. 1973. Soil Survey of Boone, Campbell, and Kenton Counties, Kentucky. USDA, Soil Conservation Service. U.S. Govt. Printing Office, Washington, D. C. 67 pp.

Description and Breaking of Dormancy in Corms of Jack-in-the-Pulpit *Arisaema* spp.[1]

TIM T. ELLIS[2] AND VARLEY E. WIEDEMAN
Department of Biology, University of Louisville, Louisville, Kentucky 40208

ABSTRACT

Corms of jack-in-the-pulpit can be arrayed in 4 size and/or developmental categories. Dormancy is temperature controlled with a chilling period of 2 to 3 months at 4 C capable of breaking dormancy of the corms. Only corms of the larger categories produced blossoms. Gibberellic acid in a lanolin paste appeared to have no effect in breaking dormancy at the 2 concentrations applied.

INTRODUCTION

In the deciduous forests of the southeastern United States, a large number of higher plant species are regarded as herbaceous perennials. These organisms reproduce vegetatively by means of modified stems such as bulbs, corms, rhizomes, stolons, and tubers. Unfortunately, much of the older literature on this subject referred to these anatomically distinct organs as rootstocks, an ill-defined term.

Hartsema (1961) reviewed the subject of the influence of temperature on flower formation and flowering in bulbous and tuberous plants. He indicated that little work of a physiological nature has been done on plants other than those of economic importance. Another review, by Rees (1966), correlated the lack of investigation into the physiology of uncultivated herbaceous perennials. Both of those articles noted that the most widely studied plants in this connection are the genera *Allium*, *Gladiolus*, *Hyacinthus*, *Iris*, *Lilium*, *Narcissus*, *Solanum*, and *Tulipa*. However, Risser (1967) and Risser and Cottam (1968) studied the influence of temperature and carbohydrate cycles on dormancy in the uncultivated spring ephemerals *Dicentra* spp. and *Erythronium* spp.

The rest period of those herbaceous perennials examined has been related to factors such as respiration, pH, enzyme activity, content of sugars, bound water, fats and lipids, changes in permeability and electrical conductivity, nitrogen compounds, especially glutathione, growth hormones, and growth inhibitors (Hemberg 1965).

The present study was undertaken with the primary intention of investigating whether cold treatments of varying lengths could break dormancy in corms of jack-in-the-pulpit *Arisaema* spp. However, it seems advantageous that several important aspects of the developmental biology of *Arisaema* be elaborated.

Many early investigations on jack-in-the-pulpit were conducted on the species recognized as *Arisaema triphyllum*. However, many of those studies may have actually been performed on *Arisaema atrorubens*, a closely related species first described by Fernald in 1940.

Camp (1932) observed that vegetative reproduction is much more common than seed production in *Arisaema*. Pollination is accomplished almost exclusively by insects because the tubular construction of the spathe prevents wind dispersal of pollen, and self-fertilization is prohibited by maturation of flowers at different times (Pickett 1915). Lateral buds, also called "bud corms," formed on the corm eventually separate from the parent corms, and after about 3 years of development usually produce small, flowering staminate plants. For several more years, the plants go through monoecious stages and may ul-

[1] Contribution No. 177 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

[2] Present Address: Department of Biology, College of Charleston, Charleston, South Carolina 29401.

timately become large, completely carpellate plants (Camp 1932). This contradicted the findings of Pickett (1915) who stated that the oldest part of any corm did not exceed 4 years. However, the reasoning behind this conclusion does not seem to have been well substantiated.

According to Schaffner (1922) the determination of sex in vegetative plants is difficult if not impossible. He concluded that the sex of the plants was independent of hereditary factors but controlled by environmental conditions. In 1935, Schaffner stated that favorable water and nutritional levels yielded a monoecious condition in *A. dracontium*, while lack of water and poor soil resulted in completely staminate plants; full pistillate plants were rarely observed.

Foerste (1891) found flower buds in *Arisaema* spp. formed within the terminal apex of intact corms as early as the middle of August in Rutland, Vermont. Pickett (1915) also noted that flower buds of *A. triphyllum* were formed during the season preceding their appearance and that most plants, with the exception of those fruiting, usually senesced by the first week of August in plants from Monroe County, Indiana. He discovered that flower emergence was between the first weeks of April and June, depending on the climate.

MATERIALS AND METHODS

The majority of the jack-in-the-pulpits taken from a moist, wooded hillside in Oldham County, Kentucky, were *Arisaema atrorubens* var. *viride*, with a completely green spathe, and *A. atrorubens* var. *zebrinum*, with variegated purple stripes on the spathe. Gradations between these 2 forms were present and did not have any particular distributional pattern. However, there were a number of plants which more closely resembled the description of *A. triphyllum* var. *pusillum* (all descriptions based on Fernald 1940). These plants were concentrated under the rocky ledges of the hillside. Vegetative plants far outnumbered those with flowers and it was difficult to positively identify them to species on the basis of vegetative characters. Braun (1967) suggested that hybridization may occur between these species. This seems quite possible because MacDougal (1901) discovered hybrids of *A. triphyllum* and *A. dracontium* (green dragon) which, based on flower morphology, are not as closely related as *A. triphyllum* and *A. atrorubens*.

TABLE 1.—JACK-IN-THE-PULPIT CORM GROUPINGS BASED ON SIZE (MM)

Size	Diameter	Length
A[1]	6–8	7–15
1	6–11	7–16
2	11–16	13–21
3	17–21	20–30
3+	21+	24+

[1] Lacked roots.

Locations of approximately 250 jack-in-the-pulpits, both vegetative and flowering, were marked with stakes in May. At the end of July, when the vegetative portions began to senesce, the corms were dug up and divided into groups on the basis of size. In addition, many of the larger corms had lateral buds (bud corms) which were removed and separately designated (Table 1). It is postulated that these sizes roughly correspond to the age groups of the plants.

Corms were collected on 31 July and 31 October and held at room temperature (approx. 25 C) until subjected to various treatments. The 31 July collections were divided into 4 groupings and subjected to cold treatments in a refrigerator at 4 C as follows: 1 group received no cold treatment and 3 groupings were treated for 1, 2, and 3 months, respectively, to cold prior to planting in the greenhouse on 31 October. The collection made from the field on 31 October received no laboratory cold treatment prior to planting on that day. Cold treated corms were subjected to their respective treatment while placed in small glass jars covered with thin plastic. All corms were potted in soil from the natural habitat as soon as the last cold treatments were completed. The pots were placed in greenhouse soil to near their tops, and

TABLE 2.—NUMBER OF JACK-IN-THE-PULPIT CORMS DEVELOPING AFTER PLANTING AS COMPARED WITH THE NUMBER PLANTED. NUMBERS IN ITALICS ARE SUMMARIZED IN TABLE 3

	Size Groupings											
	A		1		2		3 & 3+		Totals		Grand Totals	
Cold Treatment	No. developing	No. planted	No. developing	No. planted	No. developing	No. planted	No. developing	No. planted	No. developing	No. planted	No. developing	No. planted
None	0	10	0	3	0	6	2	17	2	36		
None + GA-I	0	5	0	2	0	6	0	16	0	29		
None + GA-II	0	5	0	2	0	5	1	16	1	28	3	93
1 Month	0	6	0	1	1	4	0	4	1	15		
1 Month + GA-I	0	6	0	2	0	4	0	2	0	14		
1 Month + GA-II	0	6	0	2	0	4	1	2	1	14	2	43
2 Months	0	6	*2*	*3*	*2*	*3*	*4*	*4*	8	16		
2 Months + GA-I	0	6	*1*	*2*	*1*	*4*	*5*	*5*	7	17		
2 Months + GA-II	0	6	*1*	*2*	*4*	*4*	*4*	*4*	9	16	*24/24*	*49/31*
3 Months	1	6	*3*	*3*	*4*	*4*	*4*	*4*	12	17		
3 Months + GA-I	1	6	*1*	*2*	*3*	*4*	*5*	*5*	10	17		
3 Months + GA-II	0	6	*2*	*2*	*3*	*4*	*4*	*5*	9	17	31/29	51/33

moisture was provided by watering between the plants. About every 7 days all pots were sprinkled. Greenhouse temperatures were 17–19 C at night and 27–29 C during the day.

Size groupings of corms were also treated with gibberellic acid in a lanolin paste after the various cold treatments as follows: (1) categories A and 1 treated with 2 levels of gibberellic acid; GA-I being 5.5 μg and GA-II 12.5 μg in 0.05 ml lanolin paste, respectively, (2) category 2 with GA-I being 11.0 and GA-II 25 μg of gibberellic acid in 0.10 ml of lanolin paste, (3) category 3 and 3+ with GA-I of 22.0 and GA-II of 50 μg gibberellic acid in 0.20 ml of lanolin. The specified amounts of gibberellic acid-lanolin paste were applied to the terminal portion of the shoot apex of the corm and covered with a small piece of thin plastic.

RESULTS AND DISCUSSION

The data for these experiments (Table 2) suggest that cold treatments of 2 or 3 months were sufficient to break dormancy in the mature corms. The relationship of size and percentage of development (Table 3) refers to those plants indicated by numbers in italics in Table 2. As indicated by the percentages, the larger, older corms were more responsive to cold treatments. Also, it is indicated that a slightly higher percentage of the plants cold treated for 3 months developed than did those with 2 months of cold treatment. The gibber-

TABLE 3.—PLANTS DEVELOPING, BASED ON CORM SIZE IN JACK-IN-THE-PULPIT

Cold Treatment [1]	Size Groupings							
	1		2		3		1 + 2 + 3	
2 Months	4 of 7	57%	7 of 11	64%	13 of 13	100%	24 of 31	78%
3 Months	6 of 7	83%	10 of 12	83%	13 of 14	93%	29 of 33	88%
Totals	10 of 14	72%	17 of 23	74%	26 of 27	96%	53 of 64	83%

[1] Includes plants with gibberellic acid treatment.

ellic acid concentrations employed did not influence the breaking of dormancy, and may have had the effect of slightly reducing the percentage of corms developing.

The plants emerging from the corms whose dormancy was broken were observed to follow a pattern of development similar to that in nature. The plants that developed did so between 2 and 6 weeks. Plants that bloomed did so in 4 to 8 weeks. The majority of the plants were completely vegetative and only 12, all at least in size category 3, had flowers. Most of the flowering plants were principally staminate and followed the normal pattern of senescence of the flowering stalk, about 7 to 10 days after emergence. As noted earlier, the flowers varied in their degree of variegation of the spathe. Complete senescence of the plants occurred about 3 months after their initial development.

In conclusion, 4 major points can be inferred from the foregoing studies: (1) cold treatment of 4 C in excess of 1 month but not necessarily 2 months was sufficient to break dormancy in mature corms of jack-in-the-pulpit; (2) the size of the corm was somewhat related to its sensitivity to cold treatment with the larger, older corms being more sensitive. There must be some as yet unexplained physiological difference between the bud corms and first-year corms which would account for the difference in sensitivity to cold treatment; (3) those concentrations of gibberellic acid employed did not enhance the breaking of dormancy, in fact, there appeared to be a slight inhibition of the percentage of corms developing; (4) those plants developing from corms whose dormancy was broken appeared to follow the sequence observed in nature.

LITERATURE CITED

BRAUN, E. L. 1967. The Monocotyledoneae. Ohio State Univ. Press, Columbus, Ohio. 464 pp.

CAMP, W. H. 1932. Sex in *Arisaema triphyllum*. Ohio J. Sci. 32:145–151.

FERNALD, M. L. 1940. What is *Arisaema triphyllum*? Rhodora 42:247–254.

FOERSTE, A. F. 1891. On the formation of the flower buds of spring blossoming plants during the preceding summer. Bull. Torrey Bot. Club 18:101–106.

HARTSEMA, A. M. 1961. Influence of temperature on the flower formation and flowering of bulbous and tuberous plants. *In* W. Ruhland (ed.). Encyclopedia of Plant Physiology. Springer-Verlag, Berlin XVI:123–167.

HEMBERG, T. 1965. The significance of inhibition and other chemical factors of plant origin in the induction and breaking of rest periods. *In* W. Ruhland (ed.). Encyclopedia of Plant Physiology. Springer-Verlag, Berlin XV(2): 669–697.

MACDOUGAL, D. T. 1901. Seedlings of *Arisaema*. Torreya. 1:2–5.

PICKETT, F. L. 1915. A contribution to our knowledge of *Arisaema triphyllum*. Mem. Torrey Bot. Club 16:1–55.

REES, A. R. 1966. The physiology of ornamental bulbous plants. Bot. Rev. 32:1–23.

RISSER, P. G. 1967. Influence of temperature on the dormancy of some spring ephemerals. Ecology 48:500–503.

————, AND G. COTTAM. 1968. Carbohydrate cycles in the bulbs of some spring ephemerals. Bull. Torrey Bot. Club, 95:359–369.

SCHAFFNER, J. H. 1922. Control of the sexual state in *Arisaema triphyllum* and *A. dracontium*. Amer. J. Bot. 9:72–78.

————. 1935. Observations and experiments on sex in plants. Bull. Torrey Bot. Club 62:387–401.

The Genus *Justicia* L. (Acanthaceae) in North Carolina

E. O. Beal
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101
and
S. F. Brown
Columbia, Missouri 65201

Abstract

The genus *Justicia* L. is represented in North Carolina by 2 taxa, *J. americana* (L.) Vahl and *J. ovata* (Walt.) Lindau. Morphologically intermediate plants occur primarily in the Coastal Plain and are especially abundant in the northern portions of the Coastal Plain. Both the scatter diagram analysis, using reproductive as well as vegetative features, and the double index analysis, using only vegetative features, indicate that the distinctness of the 2 taxa may be more apparent than real. Experimental studies are suggested as a means of solving the problem.

Introduction

In the process of preparing the section on *Justicia* L. for the authors' forthcoming "Marsh and Aquatic Flora of North Carolina" it became evident that the 2 species in North Carolina, *J. americana* (L.) Vahl and *J. ovata* (Walt.) Lindau, do not exhibit complete morphological discontinuity in the state. As a means of visualizing that variability, (1) the distributions of the taxa and morphological intermediates were mapped, (2) a "scatter diagram" of pertinent characters was prepared, and (3) the double index analysis of Klekowski and Beal (1965) was applied.

Materials and Methods

Seventy-four specimens from the herbaria of North Carolina State University (NCS), Duke University (DUKE), the University of North Carolina at Chapel Hill (NCU), and from the senior author's own collection were utilized. These specimens represented distinct geographical populations, were either mature flowering or fruiting specimens, and were not duplicates from 1 population. In 2 instances, 2 specimens were from nearby geographical areas and of the same taxon. Thus, the map (Fig. 1) presents only 72 "dots." Of the 74 specimens analyzed in the "scatter diagram" (Fig. 2), 71 were sufficiently complete for use in the double index analysis (Figs. 3, 4).

Discussion

As is evident in Fig. 1, *J. americana* is the sole representative of the genus in the Blue Ridge and Piedmont provinces of North Carolina, *J. ovata* being limited to the Coastal Plain Province. *Justicia americana* is also present throughout the northern portion of the Coastal Plain. In this area of sympatry, plants of various degrees of morphological intermediacy are abundant. In addition, plants of a morphologically intermediate nature are also present throughout the remainder of the distribution of *J. ovata* in North Carolina, although less abundant.

The degree of variability, indicated roughly in Fig. 1, is expressed with greater discrimination in Fig. 2. Here, the individual "key characters" used by Fernald (1950), Gleason (1952), Small (1933), and Radford et al. (1968) in distinguishing between *J. americana* and *J. ovata*, as well as 2 leaf venation features which we have found to be as consistent as those key characters previously in use, are symbolically presented for each of the 74 speci-

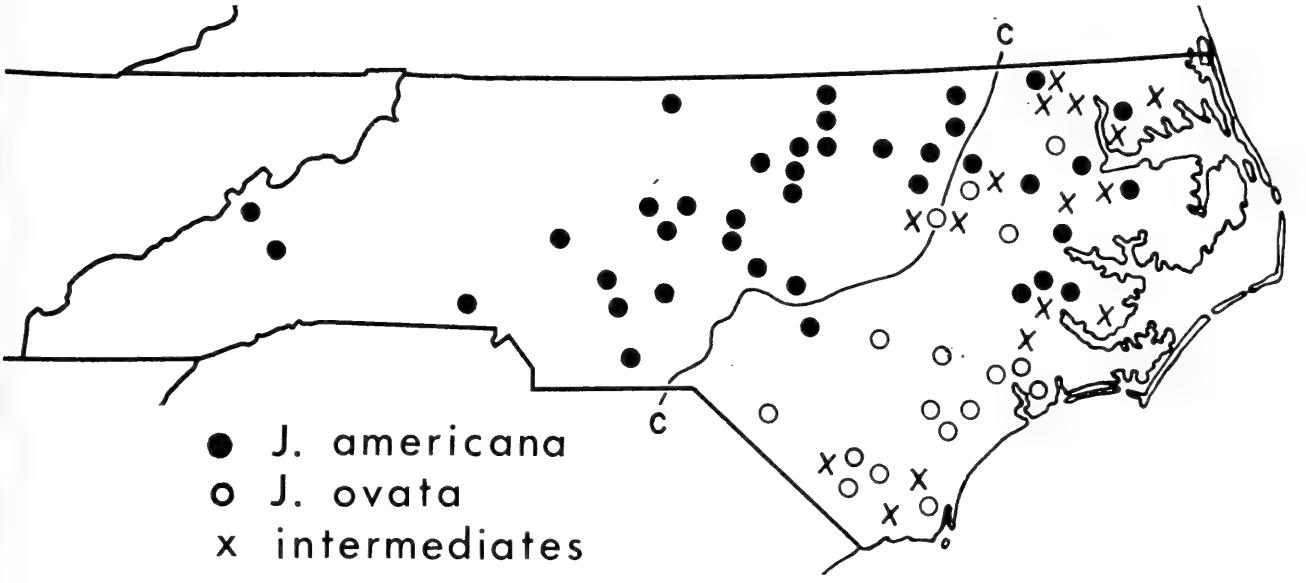


Fig. 1. Distribution of *Justicia* specimens analyzed in this study. c–c is the boundary between the Coastal Plain and Piedmont provinces of North Carolina.

mens. The leaf venation features we have added are (1) the degree of vein distinctness and (2) the presence or absence of vein anastomoses, with *J. americana* possessing indistinct veins which anastomose frequently, in contrast to *J. ovata* which possesses leaves with distinct venation and few, if any, anastomoses.

The North Carolina specimens do not plot as 2 isolated groups of uniform fea-

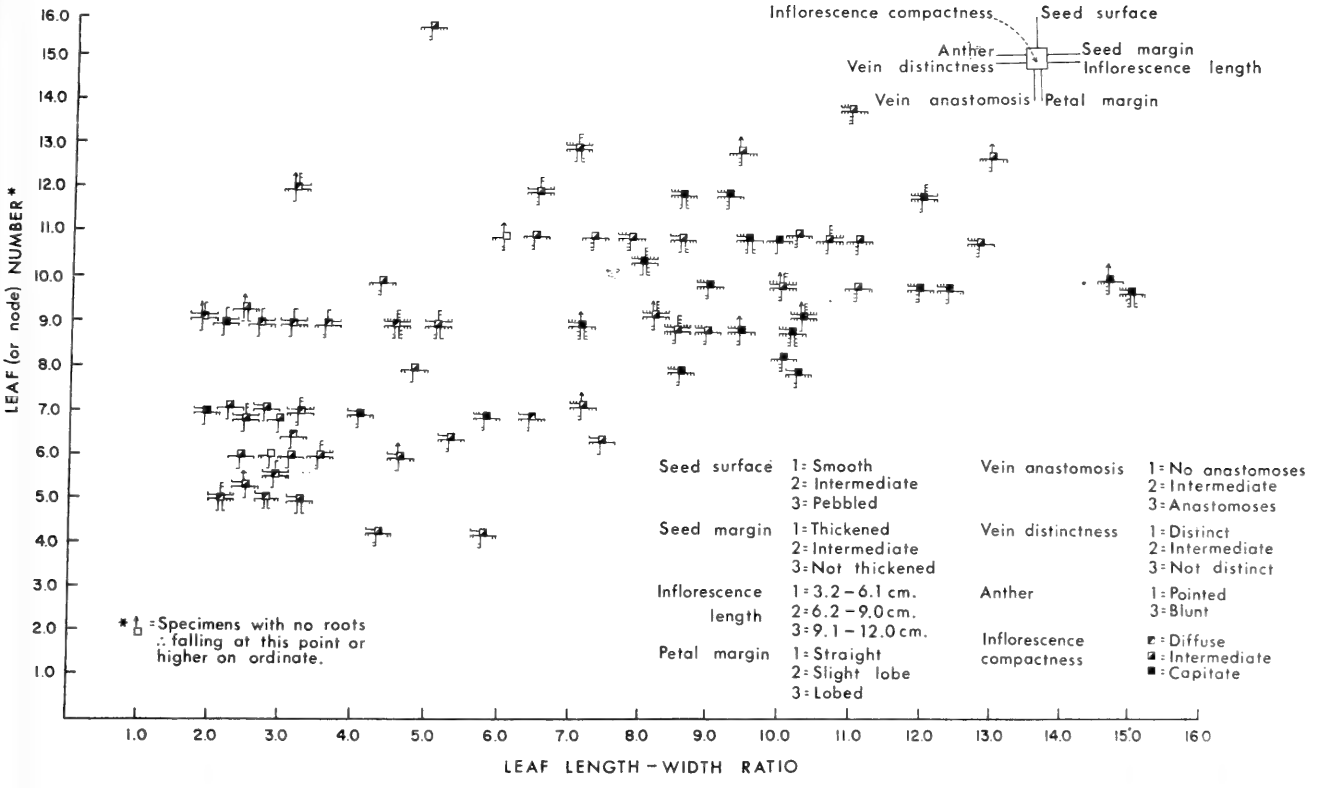


Fig. 2. Scatter diagram of 74 *Justicia* specimens from North Carolina. *Justicia ovata* plots toward the lower left and *J. americana* toward the upper right. Characters not available on herbarium specimens are indicated by missing lines and open squares.

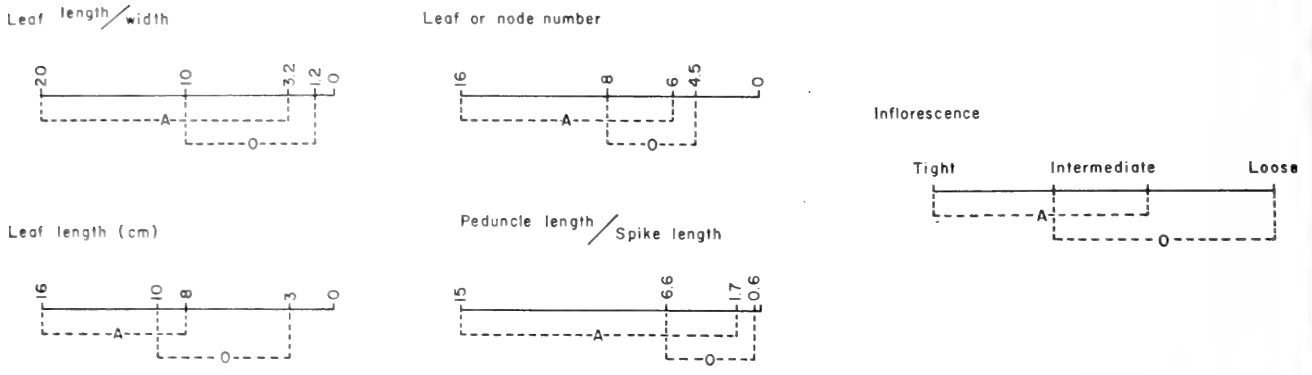


FIG. 3. Published ranges for morphological features of *J. americana* (A) and *J. ovata* (O) utilized in the double index analysis of Fig. 4.

tures (Fig. 2). Rather, 2 general groupings of an indistinct nature occur in which individual "key characters" are not restricted to the appropriate groups.

To further quantify the extent of variability among populations of *Justicia* in North Carolina, the double index analysis (Klekowski and Beal 1965), was utilized. The key characters presented in the manuals noted above and used in determining limits for double indices (Fig. 3) were selected on the basis of providing the greatest possible sample size. Thus, features of flowers and seeds were not used in this analysis since few herbarium specimens possessed both flowers and seeds.

In brief, the double index technique permits each specimen to be graded in terms of its morphological similarity to both species for each character examined, in this case 5 (Fig. 3). If a particular specimen exhibited a characteristic limited to 1 species it received a score of 1 for that taxon and a score of 0 for the other. If a particular specimen exhibited a characteristic in the area of overlap, it received a score of 1 for each taxon. Thus, if a specimen exhibited all 5 characteristics which are limited to one species, it would have a score of 5 for that taxon and a score of 0 for the other. On the other extreme, if the 5 characteristics all fell within the areas of overlap, that specimen would be scored 5 for both taxa. As indicated in Fig. 4A, one specimen did just that.

Of the 71 collections of *Justicia* from North Carolina thus analyzed for 5 key characters and plotted according to their "*americana*" and "*ovata*" indices (Fig. 4A), 21 percent proved to be exclusively "*ovata*," 46 percent exclusively "*americana*," and 33 percent possessed some degree of intermediacy, with 14 percent of the total being exactly intermediate between "*americana*" and "*ovata*."

Upon subdivision of the above 71 collections into geographical units, the plants from the southern half of the Coastal Plain exhibited chiefly the morphological features of "*ovata*" and intermediates closely related to "*ovata*" (Fig. 4B). Plants from the northern half of the Coastal Plain, however, indicated a shift in morphological features toward "*americana*" (Fig. 4C). Plants from areas west of the Coastal Plain exhibited a more complete shift to the morphological features of "*americana*" (Fig. 4D).

Whether the pattern of variation in *Justicia* as described above is ecophenic or ecotypic is a matter open to question. So is the degree of fertility of the plants within and among populations. The pattern of variability does, however, suggest that the distinctness of *J. americana* and *J. ovata*, as species, may be more apparent than real.

Justicia might provide a good example of genotypic selection by local environmental conditions in which the extreme forms are recognizable easily as phenotypic species yet are biologically only ecotypic extremes of a single polymorphic species. It appears that *Justicia*, especially those

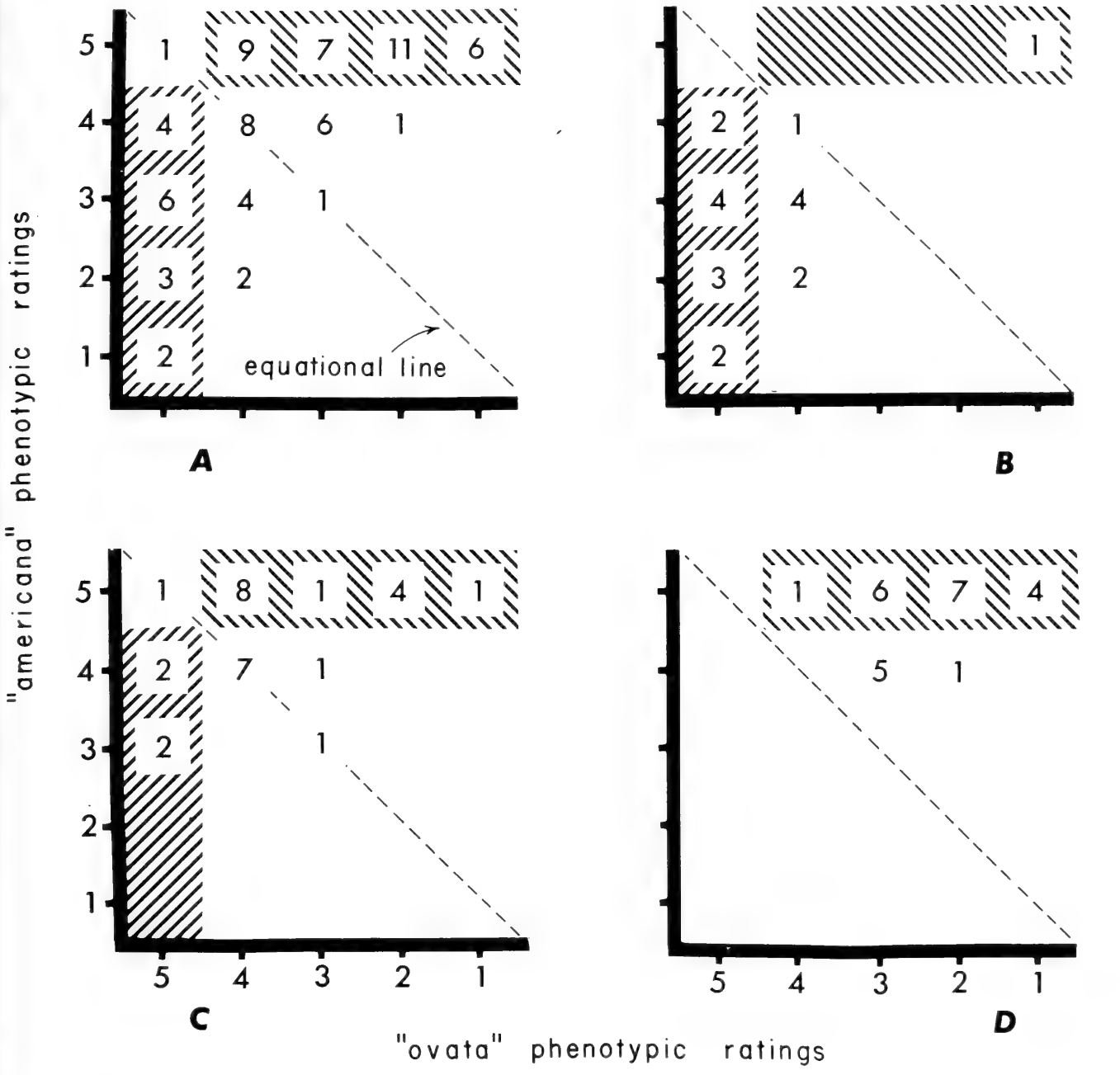


Fig. 4. A–D, specimens of *Justicia* from North Carolina plotted according to their double index. Shaded areas indicate those specimens in which all 5 characteristics are within the published ranges of either species. The number of specimens plotted at each point is recorded at that point. The equational line is an arbitrary line defined by *"americana–ovata"* phenotypic ratings of equal magnitude. A, all specimens from North Carolina. B, specimens from the southern half of the Coastal Plain. C, specimens from the northern half of the Coastal Plain. D, specimens from areas west of the Coastal Plain.

representatives in northeastern North Carolina, would be an excellent subject for experimental analysis and that the species herein discussed might fit the theoretical pattern discussed by Ehrlich and Raven (1969) and modelled by Endler (1973) very closely.

Literature Cited

Endler, J. A. 1973. Gene flow and population differentiation. Science 179:243–250.

Ehrlich, P. R., and P. H. Raven. 1969. Differentiation of populations. Science 165: 1228–1232.

Fernald, M. L. 1950. Gray's Manual of Botany. Amer. Book Co. New York, N.Y. 1632 pp.

GLEASON, H. A. 1952. The New Britton and Brown Illustrated Flora. Vol. 3. Lancaster Press, Inc., Lancaster, Pa. 595 pp.

KLEKOWSKI, E. J., AND E. O. BEAL. 1965. A study of variation in the *Potamogeton capillaceus–diversifolius* complex (Potamogetonaceae). Brittonia 17(2):175–181.

RADFORD, A. E., H. E. AHLES, AND C. R. BELL. 1968. Manual of the Vascular Flora of the Carolinas. Univ. N. Carolina Press. Chapel Hill, N.C. 1183 pp.

SMALL, J. K. 1933. Manual of the Southeastern Flora. Univ. N. Carolina Press. Chapel Hill, N.C. 1554 pp.

Notes on the Flora of the Sinking Creek System and Elkhorn Source Areas in the Inner Blue Grass Region of Kentucky

Willem Meijer
Thomas Hunt Morgan School of Biological Sciences, University of Kentucky, Lexington, Kentucky 40506

Abstract

Little known relict plant communities investigated in the Inner Blue Grass Region along Sinking Creek between Jessamine Creek and Roaring Springs and along outliers of South and North Elkhorn creeks suggest that before the arrival of the first white settlers the area was partly covered by swamp forests possibly still in connection with those along the lower Ohio and Mississippi rivers.

Three localities of *Taxodium distichum*, 2 with trees over 200 years old, 6 localities of *Quercus bicolor*, 1 with about 200 trees, and 1 locality of *Quercus lyrata* were discovered in the area.

The orchid *Spiranthes cernua* var. *odorata* is locally common along Sinking Creek, in association with *Chelone glabra* and *Carex hyalinolepis*. The mimosoid legume *Desmanthes illinoensis* has its most eastern locality along Sinking Creek in Woodford County.

Introduction

This paper is a preliminary floristic note on the relict flora of the Inner Blue Grass Region investigated in cooperation with members of the Buckley Hills Audubon Wildlife Society and Woodford County Save the Land Association, especially along a series of sinkholes and sinking creeks that stretches from Ashgrove Pike near the Lexington–Nicholasville road west of the Hickman Creek sewage disposal plant through the northern part of Jessamine County, along Versailles and towards Midway in Woodford County, and ending in Roaring Springs in northeastern Franklin County. Part of this system was described by Jillson (1945).

Increased interest in this area has been shown by landowners who benefit from clearwater springs from caves and underground streams, feeding creeks and natural ponds.

Problems of land use and zoning and the great lack of open space for nature recreation in the Inner Blue Grass Region have raised new interest in the geology, flora, and fauna of this karst landscape. Encroaching housing developments, trailer parks, and industrial development threaten the last remains of the once rich swamp flora of the creeks and sinkholes along this system.

Acknowledgments

Field work was done during the spring and summer of 1974 in cooperation with Mr. Ellwood Carr, Mr. Van Ship, Mrs. Alex Bowen, Mrs. El. Jones, and Mrs. Patricia DeCamp of the Buckley Hills Audubon Society who acted as guides and companions in the area and who introduced the author to landowners on the farms around Sinking Creek. My former students John MacGregor and Max Leach, the latter now forester in Madisonville, directed me to localities of *Taxodium distichum* in Jessamine and Fayette counties. Mr. Harold R. Wallace, District Conservationist for Jessamine and Fayette counties, joined me in exploration of the Delaney Ferry Road section of Sinking Creek.

Methods

The study area was divided into sections on the basis of topography, and separate lists of floristic notes and herbarium collections were kept for each area. Identi-

FIG. 1. *Taxodium distichum* near Old Frankfort Pike, Mr. Proctor's home, Lexington, Kentucky.

fications of specimens were made in the field or later in the herbarium.

The project stimulated renewed studies of the difficult genus *Carex* of which around 85 species are known from Kentucky. A combination of an unpublished key for this genus for Kentucky (Meijer unpublished), text and illustrations by Mackenzie (1931, 1940) for the Flora of North America, and authentic specimens in the herbarium made it possible to identify species in a reliable way.

RESULTS

Bryophyta

Fissidens grandifrons Brid.—This is an aquatic moss observed in Cogar Springs south of Midway, in Gay Spring, and in the Alexander Spring and along a creek near Parkers Mill Road, Lexington. Crum (1973) mentioned it from the Great Lakes forest in Michigan and referred to it as widespread in North America south to Guatemala. No specimens were reported from Kentucky by Fulford and Shacklette (1942). This moss seems to be typical for clear water in cold springs in limestone. According to Dr. A. J. Sharp (Univ. Tennessee, pers. comm.) it has been found at similar locations in Tennessee. The range given by Grout (1936) is southern Canada, Alberta to Ontario, Washington to California, east to New York, West Virginia, and Tennessee.

Gymnosperms

Taxodiaceae

Taxodium distichum (L.) Rich, Bald Cypress.—A population of 5 trees was discovered along Beals Branch on the Crosbey's farm just south of the Old Frankfort Pike southwest of Midway in Woodford County.

Measurements of trees at breast height were:

	Girth			Diameter	
	feet	inches	cm	inches	cm
No. 1	16	8	510	63	160
No. 2	12		366	45.8	116
No. 3	10		305	38	96
No. 4	9	2	279	35	89
No. 5	7	4.5	225	28	71

According to Fowells (1965), second growth stands of *Taxodium distichum* in Maryland have trees 100 years of age with diameter of 21.3 inches (54 cm) and a diameter increase of about 2 inches (5 cm) every 10-year period.

Fowells (1965) stated that there is good evidence that diameter growth in Louisiana also is 2 inches (5 cm) in 10 years. Even if we assume that on the fertile soils of the Inner Blue Grass Region this tree would grow 0.25 inch (6 mm) per year instead of 0.20 inch (5 mm) as in Maryland and Louisiana, the estimated age of the tree with 63 inches diameter would be more than 200 years. At an increase in diameter of 2 inches in 10 years, the age would be around 300 years.

A second relict locality of *Taxodium distichum* was discovered by John Mac-

Gregor along Linden Lane in Jessamine County in southern Nicholasville just west of Highway 27 near a former pond still shown at the northern margin of Little Hickman Topographic Quadrangle, 1952 edition. Two trees measuring 91 and 86.5 inches (227.5 and 215 cm, respectively) in girth, approximately 120–140 years old, grew here in company of *Platanus occidentalis*, *Quercus macrocarpa* (girth, 10 feet; 3.05 m), *Juglans nigra*, and *Carya laciniosa* in a former farmland without any trace of planted trees around them.

The third locality of bald cypress (Fig. 1) discovered by Max Leach is in Fayette County along the Old Paris Pike west of Interstate 75 northwest of Bryan Station High School on the land of Mr. Proctor. The girths of the trees were:

No. 1—21 feet 6 inches at base ca 15 feet at main bole	655 cm
No. 2—9 feet, 2 inches	279 cm
No. 3—6 feet, 9 inches	206 cm
No. 4—7 feet	213 cm
No. 5—9 feet	274 cm
No. 6—17 feet	518 cm
No. 7—4 feet, 5 inches	122 cm
No. 8—6 inches	15 cm

Several trees grow around a natural pond fed by a spring. The young tree of 6-inch (15-cm) girth shows that the species is still regenerating at this locality.

On the adjacent property of Mr. Owen Hitt, the girths of the following trees were:

	Feet	Inches	cm
No. 1	8	11	272
No. 2	11	4	345
No. 3	7	9	236
No. 4	12	7	383
No. 5	13	9	419

If we assume that trees of about 12 feet (366 cm) girth are about 200 years old at the growth rate of 2 inches per 10 years then there are at least 4 out of a population of 13 trees older than 200 years. From these data it seems well established that bald cypress grew in the Inner Blue Grass Region before the arrival of the first white settlers. The localities in the Inner Blue Grass Region are disjunct from the main range of this species. (See map 84E in Little 1971.)

FIG. 2. The historical specimen of *Heteranthera limosa* collected by C. W. Short in 1838 near Cole's Tavern on the Frankfort Road in Woodford County.

Monocotyledons

Pontederiaceae

Heteranthera limosa (Sw.) Willd., Smaller Mud Plantain.—A specimen in the Herbarium of the School of Biological Sciences, University of Kentucky collected by C. W. Short in 1838 (Fig. 2) is labeled "A Pond near Cole's Tavern on the Frankfort Road, never seen elsewhere." This is the only locality of this plant reported from Kentucky. Lucy Braun (1943) reported it as being in the University of Cincinnati Herbarium without locality. The genus ranges from the tropics to North America. Fernald (1950) reported the range of this species as Florida to New Mexico, north

FIG. 3. *Spiranthes cernua* var. *odorata* Correll in swamp along Lees Branch, Woodford County, 28 September 1974.

FIG. 4. *Chelone glabra* turtlehead. In swamp along Lees Branch, Woodford County.

to Kentucky, southern Illinois, Minnesota, Nebraska, and Colorado. A good illustration is given by Mohlenbrock (1970). The map in Muenscher (1944) is incomplete though it added Virginia to the range. Through the kind assistance of Mr. and Mrs. Richard DeCamp, Lexington, I contacted Mr. W. Julian Walden, Versailles Pike near Nugents Cross Roads at the junction of the Old Frankfort Pike with the Versailles–Midway Road, who informed me that Cole's Tavern was the Black Horse Tavern at the stage stop near the crossroads. There is a pond along Lees Branch just east of this place but I could not find any specimens of *Heteranthera* there. A more systematic search of natural farm ponds or old oxbow lakes in Kentucky might well turn up new localities of this rare water plant.

Orchidaceae

Spiranthes cernua (L.) Richard.—This orchid (Fig. 3) occurs abundantly in wet meadows, around swamps filled with turtle head *Chelone glabra* (Fig. 4), *Lobelia cardinalis*, *Asclepias incarnata*, and *Leersia oryzoides* along the margin of the swampy valley along Lees Branch just south of the Old Frankfort Pike in Woodford County. It formed impressive colorful vegetation in September 1974 in places full of blue flowering *Lobelia siphilitica*. Lucy Braun (1943) only mentioned it in Laurel, Letcher, Menifee, Montgomery, and Rowan counties. Recent discoveries were made of this orchid near Clay City in Powell County and along Chimney Creek in Wolfe County in the Red River Gorge. As a consequence of mowing in the locality in October 1974, or the dry summer of 1975 or too much grazing, no flowering plants could be found along Lees Branch in September 1975. It is unlikely that the flora at this locality, unique for Woodford County, will survive with continued heavy grazing.

Cyperaceae

The Sinking Creek System is the best place in the Blue Grass Region to study

genera and species of this much neglected family. The greatest concentration of species can be found along Lees Branch where the cool, clear, running creek is lined with a swamp community of *Scirpus lineatus*, *Scirpus atrovirens*, *Scirpus validus*, *Cyperus strigosus*, *Eleocharis palustris* (possibly new for Kentucky, at the southern boundary of its range, see Map 162 in Muenscher [1944]), *Eleocharis obtusa*, and species of *Carex*.

The latter genus contains at least 85 species in Kentucky (Braun 1943). It is one of the most suitable genera to indicate species diversity of natural areas.

The distribution of species of Carex in the 2 most swampy sections of the Sinking Creek system is as follows (+ only one colony, × fairly common, ×× common):

	Lees Branch	Delaney Ferry
C. blanda	×	—
C. stipata	××	××
C. shortiana	×	×
C. granularis	××	××
C. lurida	×	×
C. lupulina	××	×
C. hyalinolepis (= *C. riparia* var. *lacustris*)	+	—
C. normalis	××	×
C. vulpinoidea	××	××
C. frankii	—	×
C. leavenworthii	—	×
C. amphibola	—	×
C. cephalophora	—	×
C. jamesii	—	×

Carex lupulina has also been recorded in the Brannon–Catnip section which needs further investigation of its *Carex* flora during spring.

The rarest *Carex* among these species is *C. hyalinolepis* Steudel syn. *C. riparia* var. *lacustris* (Willd.) Kükenth.

This form is so far only known from western Kentucky where it was collected by Jim Conrad and Amy Boyarsky, Coll. No. 1660, 16 June 1971 in Marshall County, 2 miles (5.2 km) south-southwest of Kentucky Dam Village State Park, in Muehlenberg County (Jim Conrad Coll. No. 635), and from a swamp in the Backbone old bend of the Elkhorn Creek northeast of Frankfort.

This species is closely related to, if not identical with, the European *Carex riparia*, well known to the present author from swamps in the Netherlands.

Dicotyledons

Ranunculaceae

Ranunculus, section *Batrachium*, Water Crowfoot.—From records in Muenscher (1944) and Fernald (1950), it appears that only 1 species of white flowering water crowfoot *Ranunculus longirostris* Godron is known from Kentucky. It has flowers with about 16 pistils which may carry 8 achenes with wrinkled more or less globular base and a curved beaked apex. The leaves have stipular sheaths which are from one-half or, more generally, three-fourths to entirely adnate to the petiole. Submerged leaves stay firm when lifted from the water. On 10 May 1974, we collected flowering and fruiting material of this species in Lees Branch quite near the Old Frankfort Pike in clear running cool water. Later on we discovered extensive patches of this species further south, some in quite shallow water on very muddy blackish soil.

Muenscher (1944) mapped this species only for western Kentucky. Lucy Braun (1943) did not mention it for the state. Short (1829) mentioned river crowfoot from the Elkhorn Creek on the Georgetown Road under the obsolete name *Ranunculus fluviatilis* (syn. *R. pantothrix* Elliott). Apparently, *R. fluviatilis* Pursh, Flora Am. Sept. 2:395, is a synonym of *R. aquatilis* Linn. Since Lees Branch is part of the Elkhorn Creek catchment area, this record may refer to *R. longirostris* also.

Fagaceae

Quercus bicolor, Swamp White Oak.—The main distribution area of this species is from western Kentucky along the lower Ohio River towards Missouri, Iowa, southeastern Minnesota, Wisconsin, southern

FIG. 5. One of the largest trees of *Quercus bicolor* swamp white oak along Lees Branch, Woodford County.

Michigan, southern Ontario and Quebec, and New England. Localities in Tennessee, North Carolina, and Virginia are rather scattered. The map of the distribution given by Little (1971) shows the absence of this species in the Eastern Coal Fields (Cumberland Plateau) in Kentucky, except in Laurel and Whitley counties and in parts of the Inner Blue Grass Region. However, Anderson County, where Dr. William Bryant showed me this tree in swamp forests along an old course of the Kentucky River, has to be added, and a new locality was discovered by the author with John MacGregor and Charles Andre in the Broadhead Quadrangle, Rockcastle County; to this can be added a locality in Trumbo Bottom south of Frankfort, Franklin County, a collection by Dr. Mary Wharton along the Kentucky River in Henry County (University of Kentucky, School of Biological Sciences Herbarium), and a locality west of Georgetown discovered by Mr. J. W. Singer of Singer's Garden, Stamping Ground and others along Elkhorn Creeks and the Kentucky River north of Frankfort surveyed by me in August–September 1975. Swamp white oak occurs in Kentucky as far south as the lower Licking River flats, in Fleming and Bath counties, Little Laurel River in Laurel County, Caney Creek in Lincoln County, the headwaters of the Dix River near Crab Orchard, and the headwaters of the Green River in Casey and Adair counties. The Sinking Creek system of the Inner Blue Grass Region contains *Quercus bicolor* in all sections where there is a rather wide valley developed: Ashbrook Pike, Brannon–Catnip, Delaney Ferry, and Lees Branch.

A rather well preserved locality is the Delaney Ferry section where this species occurs scattered through forest dominated by *Fraxinus americana*. Along Lees Branch, 1 large tree (Fig. 5) was found in the northern part a few minutes walk from the Old Frankfort Pike, and a much larger stand of about 200 trees in the southern part of the forested area.

In the Brannon–Catnip section, the species might be hybridizing with *Quercus lyrata*, and in the very small forest along Ashbrook Pike, 1 tree is a probable hybrid with nearby *Quercus muehlenbergii* and another with *Quercus macrocarpa*. The largest sized tree among a population of 10 trees is here about 13 feet (4 m) girth.

The species occurs in Woodford County also in the company of *Nyssa sylvatica* and *Acer rubrum* in the abandoned Warwick channel of the Kentucky River near Cloverbottom, mapped by Jillson (1947b, 1948) and along Clear Creek north of Stonehedge Farm 2 miles (3.2 km) southwest of Pinckard, Keene Top Quadrangle, only 3 miles (4.8 km) west-southwest from the Delaney Ferry section of the Sinking Creek in Jessamine County.

The suspected hybrids of swamp white oak along Ashgrove Pike and south of Brannon Road would suggest that fruits are not dispersed very far from the mother trees by water or rodents. However, long-distance dispersal of this species over the

FIG. 6. *Quercus lyrata* overcup oak, from swamp forest near Brannon Road, Jessamine County.

postglacial plains north of the Ohio River might well be done by wood ducks (Fowells 1965). Seeds float in the water below the trees in the fall.

Quercus lyrata, Overcup Oak.—A colony of 3 trees (Fig. 6) was discovered 20 August 1974 in a swamp forest with permanently stagnant water with *Alisma subcordata*, *Boehmeria cylindrica*, *Lysimachia ciliata*, *Carex lupulina*, *Lobelia cardinalis*, and *Scutellaria lateriflora*, 1 mile (1.6 km) south of the middle of Brannon Road in Jessamine County.

The tree flora at and around this site consisted of *Carya laciniosa*, *Fraxinus americana*, *Acer rubrum*, *A. saccharinum*, *A. negundo*, *Asimina triloba*, *Tilia americana*, *Quercus macrocarpa*, *Q. muehlenbergii*, *Platanus occidentalis*, *Ulmus americana*, and *Celtis occidentalis*.

This locality of *Quercus lyrata*, a coastal plain species, similar in distribution to *Taxodium distichum*, is 150 miles (250 km) east of the main range of this species in western Kentucky and 80 miles (130 km) from a locality mapped by Little (1971) in Jefferson County, apparently in the Scottsburg lowlands.

It is remarkable how little the distributional areas of swamp *Q. bicolor* and *Q. lyrata* overlap; mainly in the lower Ohio River drainage and near the junction with the Mississippi Valley. From a close study of individual trees and leaf shapes it would appear that hybridization with *Q. bicolor* has taken place at this locality.

Leguminosae

Subfamily Mimosoideae

Desmanthus illinoensis, Illinois Mimosa.—Lucy Braun (1943) reported this species from river banks in Boone, Fulton, Gallatin, Hickman, and Oldham counties. The locality along Lees Branch, south of Old Frankfort Pike along the old Versailles–Georgetown railways track is at the eastern margin of the range of this species (Isely 1973, with map).

DISCUSSIONS AND CONCLUSIONS

A floristic survey of the Sinking Creek System, more or less parallel with the South Elkhorn Creek would suggest that it is part of what was once a continuous river drainage system similar to the former Mesozoic course of the Kentucky River across the Blue Grass Region as delineated by Jillson (1963). Further hydrological and geological work is needed to test this assumption. The streams which run at present through the Sinking Creek System are far too small to explain the extensive accumulation of alluvium and colluvium in Lees Branch and at other places. A soil depth of 12 feet (365 cm) has been established by me in a recent sinkhole on a side branch of Lees Branch south of Midway. Mr. Walden picked up a rounded granite boulder at his farm near Nugents Crossroads which must have been transported by a river. This suggests the possible existence of sandy alluvium and gravels in underground water courses with good consequences for filtration of water. A search

can be made for alluvial deposits in nearby caves which could supply pollen samples which could give clues to the vegetational history of the area. Out of a pure floristic research there might arise a combined study of landforms and vegetational history of the Blue Grass which could lend support to land use efforts to prevent the Sinking Creeks from becoming stinking creeks.

LITERATURE CITED

BRAUN, E. L. 1943. An Annotated Catalog of the Spermatophytes of Kentucky. Swift Printing Co., Cincinnati, Ohio. 161 pp.

CRUM, H. 1973. Mosses of the Great Lake Forest. Univ. Herbarium, Univ. Mich., Ann Arbor, Mich. 404 pp.

FERNALD, M. L. 1950. Gray's Manual of Botany. American Book Co., New York, N. Y. 1632 pp.

FOWELLS, H. A. 1965. Silvics of Forest Trees of the United States. Agriculture Handbook 271, U.S. Govt. Print. Off., Washington, D.C. 762 pp.

FULFORD, M., AND H. T. SHACKLETTE. 1942. A list of Kentucky Mosses. Bryologist 45:125–134.

GROUT, A. J. 1936. Moss flora of North America. Vol. 1. Publ. by Author, Newfane, Vermont.

ISELY, D. 1973. Leguminosae of the United States: I. Subfamily Mimosoideae. Mem. New York Bot. Gard. 25:1–152.

JILLSON, W. R. 1945. Geology of Roaring Spring. Roberts Printing Co., Frankfort, Ky. 44 pp.

———. 1947. Warwick Abandoned Channel of the Kentucky River. Roberts Printing Co., Frankfort, Ky.

———. 1948. Geological excursions in Kentucky. Roberts Printing Co., Frankfort, Ky. 59 pp.

———. 1963. Delineation of the Mesozoic Course of the Kentucky River Across the Inner Blue Grass Region of the State. Roberts Printing Co., Frankfort, Ky. 24 pp.

LITTLE, E. L. 1971. Atlas of United State Trees I. U.S. Dept. Agric. Misc. Publ. 1146.

MACKENZIE, K. K. 1931. Cyperaceae. Tribe 1. Cariceae. North American Flora Vol. 18(1): 1–478.

———. 1940. North American Cariceae illustrated by Harry Charles Creutzburg. I. Plates 1–269. II. Plates 270–539. New York Bot. Garden, New York, N.Y. 547 pp.

MOHLENBROCK, R. H. 1970. The Illustrated Flora of Illinois. Flowering Rush to Rushes. S. Ill. Univ. Press, Carbondale, Ill. 272 pp.

MUENSCHER, W. C. 1944. Aquatic Plants of the United States. Comstock Publ. Co., Ithaca, N. Y. 374 pp.

SHORT, E. H. 1829. Florula Lexingtoniensis. Faciculus IV. Transylvania Journ. Med. 2: 438–453.

Fisheries Investigation of a Channelized Stream, Big Muddy Creek Watershed, Kentucky

MARTIN F. GOLDEN AND CLINTON E. TWILLEY
Dames & Moore, Environmental Consultants, 1150 West Eighth Street, Cincinnati, Ohio 45203

ABSTRACT

This preliminary survey was undertaken to broaden the data base on the fishes of the Big Muddy Creek watershed, Butler and Logan counties, Kentucky. Fish collections and water quality characteristics are reported for 4 stations in the watershed for August 1974. Thirty-one species of fishes were collected during the survey, bringing the total kinds of fishes known from the Big Muddy Creek drainage to 40. Biomass and number of species were reduced significantly in channelized areas as compared to unchannelized areas. This indicates full recovery has still not occurred after 33 years, since the last channel maintenance was completed in 1941. Water quality was generally within acceptable limits established by the state of Kentucky for all sampling stations. Therefore, habitat alteration is the likely cause for the reductions in fish diversity and biomass.

INTRODUCTION

Data concerning the aquatic ecosystem of the Big Muddy Creek watershed, Butler and Logan counties, Kentucky, apparently are limited to a cooperative reconnaissance survey conducted by the Bureau of Sport Fisheries and Wildlife and the Kentucky Department of Fish and Wildlife Resources (pers. comm. 3 April 1962, Walter A. Gresh, Bureau of Sports Fisheries and Wildlife, Atlanta, Georgia). This preliminary survey was undertaken to broaden the data base by characterizing the fish communities of the Big Muddy Creek watershed and their relation to water quality and past channelization (Fig. 1) to be used in evaluating future plans for stream alteration. Past channelization of the main stem was initiated in 1929 and maintained until 1941, to improve drainage in the lower basin for agricultural purposes. This project resulted in shortening the stream about 16–24 km (10–15 miles) (Butler County Soil Conservation District et al. 1962).

ACKNOWLEDGMENTS

This project was sponsored in part by funds from the U.S. Soil Conservation Service (Lexington, Kentucky) in relation to the Big Muddy Creek Watershed Project. The authors also wish to express their thanks to the late Dr. Morgan Sisk of Murray State University for supplying portions of the data on fishes.

DESCRIPTION OF STUDY AREA

The Big Muddy Creek watershed lies in Butler and Logan counties, Kentucky, within 2 physiographic regions, the Western Coal Field and the Mississippian Plateau. Topography varies from 224 m (735 feet) to 91 m (300 feet) in elevation and is characterized by broad, gently rolling slopes. Soils within the region are composed of 4 principal associations, 1 upland and 3 lowland soil types, and are formed from limestone, sandstone, and shale (Butler County Soil Conservation District et al. 1962). Floodplain usage is predominantly agricultural.

Big Muddy Creek originates in north-central Logan County about 2.7 km (1.7 miles) east-northeast of Homer, Kentucky, and flows northward to its confluence with the Green River near Mining City, Kentucky, a distance of about 38 km (24 miles). The total watershed area of Big Muddy Creek is 26,362 ha (65,140 acres). The gradient of the upland 12.9 km (8 miles) of Big Muddy Creek is approximately 4.9 m/km (25.5 feet/mile); the

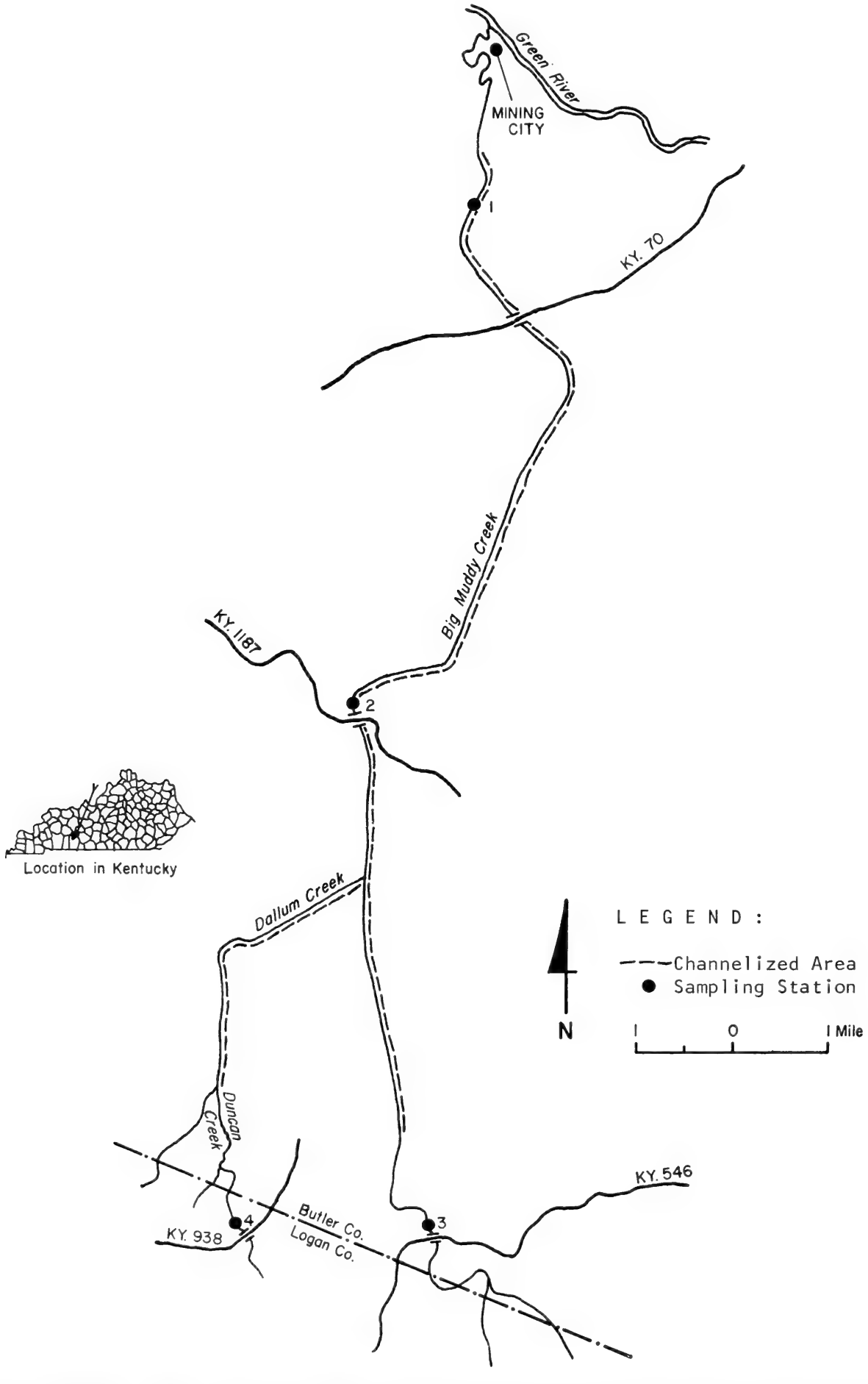


FIG. 1. Sampling stations in Big Muddy Creek watershed, Butler and Logan counties, Kentucky. Adapted from Butler County Soil Conservation District et al. (1962).

TABLE 1.—TOTAL FISH BIOMASS AND COMPOSITION BY FAMILY AT THE 3 STATIONS IN BIG MUDDY CREEK, 14–15 AUGUST 1974

	Sampling Station								
	1 0.012 ha (0.03 acre)			2 0.020 ha (0.05 acre)			3 0.016 ha (0.04 acre)		
Family	kg/ha	lb/acre	%	kg/ha	lb/acre	%	kg/ha	lb/acre	%
Clupeidae	0.57	(0.5)	1.8	3.41	(3.0)	29.1	1.14	(1.0)	2.0
Esocidae[1]	–	–	–	–	–	–	0.91	(0.8)	1.7
Catostomidae	16.70	(14.7)	49.3	3.41	(3.0)	29.1	7.27	(6.4)	12.4
Ictaluridae[2]	5.34	(4.7)	15.8	–	–	–	4.66	(4.1)	7.9
Centrarchidae	5.00	(4.4)	14.6	3.98	(3.5)	33.4	34.42	(30.3)	58.9
Sciaenidae	5.80	(5.1)	17.0	–	–	–	7.16	(6.3)	12.1
Other[3]	0.57	(0.5)	1.5	1.02	(0.9)	8.4	2.95	(2.6)	5.0
Total Biomass	33.97	(29.9)		11.93	(10.5)		58.50	(51.5)	

[1] Juvenile specimens collected were reported in "other."
[2] Excludes the tadpole madtom, genus *Noturus*.
[3] Includes minnows, topminnows, shiners, etc.

floodplain portion has an average gradient of about 0.4 m/km (2.3 feet/mile). Typically, the stream morphology ranges from shallow riffles to pools of about 1 to 2 m (3 to 6 feet) in depth. The substrate varies from coarse gravel in the headwaters to hard clay overlain by mud deposits in downstream areas.

MATERIALS AND METHODS

Four stations were established for fish and water quality sampling (Fig. 1). To determine the effects of past channelization, 3 stations were established on the main stem of Big Muddy Creek. Stations 1 and 2 were in the channelized area and Station 3 was upstream. These stations, along with Station 4 on Duncan Creek, are representative of major stream habitats in the basin. The maximum water depth at the sampling stations ranged from 1.35 to 0.75 m (4.5–2.5 feet) from Stations 1 to 4, respectively. Maximum stream width at Stations 1 and 2 was approximately 6 m (20 feet) and about 3 m (10 feet) at Stations 3 and 4. Generally, the length of stream sampled at each station varied from a minimum of about 30 m (100 feet) at Station 1 to a maximum of 60 m (200 feet) at Stations 3 and 4. Variation in area sampled (Table 1) reflects efforts to include both pool and riffle habitats. Station 2 was the only one that did not include a riffle area.

Selected water quality parameters were determined at all stations during August 1974 (Table 2). Sediment samples 2.5 cm (1 inch) in diameter and 46 cm (18 inches) deep were also obtained at the stations on Big Muddy Creek for analysis of residual pesticides. Dissolved oxygen, temperature, specific conductance, and pH were determined in the field. Dissolved oxygen was measured with a Yellow Springs Instrument Company polarographic oxygen meter (Model 57), specific conductance and temperature were measured with a Yellow Springs Instrument Company S-C-T meter (Model 33), and pH was measured with a Fisher-Accumet pH meter (Model 120). All other analyses were performed in the laboratory according to Environmental Protection Agency Guidelines Establishing Test Procedures for Analysis of Pollutants (Federal Register, 16 October 1973). The sediment samples were analyzed for residual pesticides by Analytical Bio-Chemistry Laboratories, Incorporated, Columbia, Missouri.

Fish collections at the 3 Big Muddy Creek stations were quantitatively sampled by treating a blocked area with Pro-Noxfish (S. G. Penick Company, New York, N.Y.), a rotenone emulsion. Potassium permanganate was used to neutralize the toxicant downstream. Each group of fishes (e.g., catostomids) was subsequently weighed to estimate biomass or standing crop. The

TABLE 2.—WATER QUALITY CHARACTERISTICS AT 4 LOCATIONS IN THE BIG MUDDY CREEK DRAINAGE, KENTUCKY, 16 AUGUST 1974. ALL VALUES ARE EXPRESSED IN MILLIGRAMS PER LITER EXCEPT WHERE NOTED

	Sampling Station			
	1	2	3	4
Alkalinity, Total (as $CaCO_3$)	71.3	96.7	103	164
pH	7.4	7.5	7.5	7.4
Biochemical Oxygen Demand	1.7	1.7	1.6	2.2
Chemical Oxygen Demand	17.3	13.1	17.3	11.5
Chloride	4.52	3.90	3.74	6.33
Fecal Coliform (col/100 ml)	600	700	1100	400
Fecal Streptococci (col/100 ml)	730	560	1300	490
Dissolved Oxygen	3.7	6.2	6.4	5.7
Hardness, Total (as $CaCO_3$)	105	108	111	188
Ammonia (as N)	0.24	0.16	0.16	0.12
Nitrate (as N)	0.26	0.15	0.22	0.29
Nitrite (as N)	<0.01	<0.01	<0.01	0.02
Nitrogen, Total Organic (as N)	1.20	0.89	1.40	0.73
Nitrogen, Soluble Organic (as N)	0.31	0.29	0.29	0.28
Orthophosphate (as P)	0.024	0.024	0.023	0.024
Phosphorus, Total (as P)	0.104	0.050	0.060	0.062
Specific Conductance (μmhos/cm)	170	215	220	360
Sulfate	21.8	12.3	8.6	19.3
Temperature, Air C	30	30	28	29
Temperature, Water C	25	25	25	24
Total Dissolved Solids	112	126	132	224
Total Suspended Solids	76	53	136	17
Turbidity (FTU)	67	33	49	7
Iron, Total	4.5	2.0	3.5	0.5
Potassium	3.8	2.3	2.1	3.3
Sodium	3.9	2.8	2.5	3.9

station on Duncan Creek was sampled qualitatively using a Smith and Root Model VII backpack electroshocker. The total shocking time at this station was 27.75 min. Nomenclature of fishes follows Bailey et al. (1970).

RESULTS AND DISCUSSION

Water Quality

Water quality standards for waters of the Commonwealth of Kentucky have been established by Regulation WP-41-1 of August 1971. The only water quality parameter observed to be below the acceptable limits was dissolved oxygen (4.0 mg/l) at Station 1 (Table 2); this may be attributed to drainage from a lumber mill sawdust pile 2.4 km (1.5 miles) upstream. However, agricultural runoff and domestic wastes from floodplain residents may also be a contributing factor to the low downstream dissolved oxygen. Big Muddy Creek and Duncan Creek waters were moderately hard, as defined by Sawyer and McCarty (1967), ranging from 105 to 188 mg/l total hardness. Nutrients such as phosphorus and nitrogen were high enough to support algal blooms and indicate the effect of agricultural runoff. Specific conductance ranged from 170 to 360 μmhos/cm and was well within limits (150 to 500 μmhos/cm) suggested by Ellis et al. (1946) for an unpolluted freshwater ecosystem. Residual pesticide concentrations in bottom sediments were below detection limits (Table 3).

On the basis of the water quality parameters observed, the overall water quality is good at stations upstream from the bridge over State Highway 70 about 1.6 km (1 mile) west of Dunbar. However, downstream (Station 1), an almost two-

TABLE 3.—RESULTS OF SEDIMENT ANALYSIS FOR RESIDUAL PESTICIDES AT 3 LOCATIONS IN BIG MUDDY CREEK, KENTUCKY, 16 AUGUST 1974. ALL VALUES EXPRESSED AS PARTS PER MILLION

	Sampling Station		
	1	2	3
Mirex	<0.01	<0.01	<0.01
PCB's	<0.2	<0.04	<0.2
Lindane	<0.01	<0.002	<0.01
Heptachlor	<0.01	<0.002	<0.01
Aldrin	<0.01	<0.002	<0.01
Heptachlor Epoxide	<0.02	<0.004	<0.02
β Chlordane	<0.02	<0.004	<0.02
α Chlordane	<0.02	<0.004	<0.02
p,p-DDE	<0.03	<0.006	<0.03
Dieldrin	<0.03	<0.006	<0.03
Endrin	<0.01	<0.01	<0.01
o,p-DDT	<0.01	<0.01	<0.01
p,p-DDD	<0.01	<0.01	<0.01
p,p-DDT	<0.01	<0.01	<0.01

fold increase in nutrients (ammonia and total phosphorus) and a decrease in dissolved oxygen indicate a significant reduction in water quality.

Fishes

Thirty-one species of fishes were collected during this survey (Table 4), bringing the total number of fishes known from the Big Muddy Creek drainage to 40. Of the 9 species not collected during this survey, 5 were darters, collected at the mouth of Big Muddy Creek between 1961 and 1963: *Ammocrypta pellucida, Etheostoma blennioides, Percina caprodes, Percina macrocephala,* and *Percina sciera* (pers. comm. 9 December 1974, Dr. Morgan Sisk, Murray State University). *Micropterus dolomieui, Carpoides carpio, Micropterus punctulatus,* and *Stizostedion canadense* have also been reported from the Big Muddy Creek drainage according to local citizens. The first 2 species were reported by Gresh (pers. comm. 3 April 1963) and the latter by the U.S. Soil Conservation Service, Lexington, Kentucky (undated memo).

There was an obvious downstream reduction in biomass (Table 1) and number of species (Table 4). Mean biomass was 61 percent lower at Stations 1 and 2 than at Station 3; and the reduction in numbers of species was only 11 percent. These reductions, in the portion of the Big Muddy Creek channelized in 1929, are amplified when stream order is considered. Several authors (Kuehne 1962, Harrel et al. 1967, Lotrich 1973) have confirmed the basic

TABLE 4.—NUMBERS AND KINDS OF FISHES COLLECTED AT 4 STATIONS IN THE BIG MUDDY CREEK DRAINAGE, KENTUCKY, AUGUST 1974

	Station			
	1 No.	2 No.	3 No.	4 No.
Clupeidae				
Dorosoma cepedianum	4	13	2	–
Esocidae				
Esox americanus	–	7	1	–
Cyprinidae				
Campostoma anomalum	–	–	–	16
Notemigonus crysoleucas	–	–	1	–
Notropis atherinoides	–	12	3	16
N. cornutus	–	–	7	25
N. emiliae	2	–	–	–
Pimephales notatus	–	–	–	35
P. vigilax	22	16	–	–
Semotilus atromaculatus	–	–	–	62
Catostomidae				
Erimyzon oblongus	–	–	–	6
Minytrema melanops	1	–	3	–
Moxostoma erythrurum	9	5	1	1
Ictaluridae				
Ictalurus natalis	–	–	17	10
I. punctatus	14	–	–	–
Noturus gyrinus	3	8	–	–
Aphredoderidae				
Aphredoderus sayanus	1	4	–	1
Cyprinodontidae				
Fundulus notatus	–	2	–	1
Poeciliidae				
Gambusia affinis	4	–	–	–
Atherinidae				
Labidesthes sicculus	1	–	–	–
Centrarchidae				
Centrarchus macropterus	–	–	1	–
Lepomis cyanellus	–	–	6	10
L. gulosus	4	17	11	–
L. macrochirus	35	35	26	–
L. megalotis	16	21	65	14
Micropterus salmoides	–	1	1	–
Pomoxis annularis	2	2	4	–
Percidae				
Etheostoma squamiceps	10	16	3	29
Percina maculata	4	8	9	–
Sciaenidae				
Aplodinotus grunniens	3	–	1	–
Cottidae				
Cottus carolinae	–	–	–	2

concept that diversity and biomass increase with stream order as a result of more available habitats. This concept is supported by data from Stations 4 and 3, which are second- and third-order streams, respectively. Therefore, the downstream Stations 2 and 1, where Big Muddy Creek is a fourth-order stream, should have significantly higher biomass and diversity than was observed. The percentage biomass of nongame fishes was highest at the channelized stations, while the percentage biomass of sport fishes (predominantly centrarchids) was highest at the unchannelized station (Table 4). Congdan (1971) and Allen (1969) reported only partial recovery of the fish populations in some streams in North Carolina and Missouri after 15 to 40 years. Previous channelization of Big Muddy Creek at Stations 1 and 2 may, therefore, account for the low biomass and diversity at those stations.

The cause of lowered biomass and diversity of fishes in channelized areas of Big Muddy Creek probably is due to habitat alterations as water quality appeared acceptable. Historically, impacts to the water quality of the Big Muddy Creek resulted from removal of trees and ground cover during the initial phases of channelization. However, those impacts are no longer perceivable, but the alterations of the physical habitat are still in evidence. The channelization smoothed the changes in longitudinal stream gradient which had produced riffle areas. Channelization also removed submerged cover (i.e., logs and treetops) essential to the fish. The lack of both riffles and submerged cover resulted in little change in current velocity within the channelized area for a given flow. During periods of high discharges, channelization caused increases in current velocities. These changes in natural flow patterns and removal of cover are the factors which still limit the fisheries of the channelized portions of the Big Muddy Creek. These factors affect the fish directly; and indirectly by limiting organisms in the food chain, such as benthic macroinvertebrates.

While processing the fish collections, external parasites were noted on several species of fishes at Stations 1 and 2. The most obvious of these parasites were the parasitic copepod *Lernaea* sp. and the black grub (a metacercaria of a fluke). These parasites were most abundant on the darters *Etheostoma squamiceps* and *Percina maculata* collected in August 1975. The extent of this parasitism in the Big Muddy Creek drainage has not been determined and could therefore be a subject of further study.

LITERATURE CITED

ALLEN, R. H., JR. 1969. Stream alteration and channelization as viewed by a state resource agency, Proc. Ann. Conf. Southeast. Ass. Game Fish Comm. 23:9–12.

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of common and scientific names of fishes from the United States and Canada (3rd ed.). Amer. Fish. Soc. Spec. Publ. No. 6. Washington, D.C. 150 pp.

BUTLER COUNTY SOIL CONSERVATION DISTRICT, NORTH LOGAN COUNTY SOIL CONSERVATION DISTRICT AND BIG MUDDY CREEK WATERSHED CONSERVANCY DISTRICT. 1962. Watershed work plan, Big Muddy Creek Watershed, U.S. Dept. Agric., Soil Cons. Serv., Lexington, Ky. 37 pp.

CONGDAN, J. C. 1971. Fish populations of channelized and unchannelized sections of the Chariton River, Missouri, Pp. 52–62. *In* E. Schneberger and J. Funk, eds. Stream channelization, a symposium. Spec. Publ. No. 2, North Central Div., Amer. Fish. Soc., Washington, D.C. 83 pp.

ELLIS, M. M., B. A. WESTFALL, AND M. D. ELLIS. 1946. Determination of water quality. U.S. Dept. Int., Fish Wildl. Serv. Rep. 9. Washington, D.C. 122 pp.

HARREL, R. C., B. J. DAVIS, AND T. C. DORRIS. 1967. Stream order and species diversity of fishes in an intermittent stream. Amer. Midl. Nat. 78:428–436.

KUEHNE, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43:608–614.

LOTRICH, V. A. 1973. Growth, production, and community composition of fishes inhabiting a first-, second-, and third-order stream of eastern Kentucky. Ecol. Monogr. 43:377–937.

SAWYER, C. N., AND P. L. MCCARTY. 1967. Chemistry for sanitary engineers. McGraw-Hill Book Co., New York, N.Y. 518 pp.

The Sex, Age, and Weight Structure of the Canada Goose Flock of Ballard County, Kentucky

WILLIAM J. RENEAU
Hunting and Conservation Division, National Rifle Association,
Washington, D.C. 20036

and

WARD RUDERSDORF
Department of Biological Sciences, Eastern Kentucky University,
Richmond, Kentucky 40475

ABSTRACT

The sex, age, and weight structure of Canada geese (*Branta canadensis*), Ballard County, Kentucky, identified the weight range of 500 *B. c. interior* as 2,353–5,585 g (5.19–12.31 lb) with a mean of 3,435 g (7.57 lb). Twelve geese weighed more than 4,537 g (10 lb) suggesting the possibility of the presence of *B. c. maxima.* The population had respective sex and age ratios of 107.5 males/100 females and 262.3 immatures/100 adults.

INTRODUCTION

The sex, age, and weight structure of Canada goose flocks (*Branta canadensis*) inhabiting the Mississippi Valley has been documented by several researchers. In southern Illinois, Elder (1946) and Hanson (1965) reported data for the Horseshoe Lake flock, and Raveling (1968) reported on the Crab Orchard flock. The flocks of southwestern Michigan have been reported by Friley (1960) and Rudersdorf (1962, unpublished doctoral dissertation, Michigan State University, East Lansing, Michigan).

The purpose of this study was to report on the sex, age, and weight structure of Canada geese utilizing the Ballard County Wildlife Management Area of Ballard County, Kentucky. Though some undetermined portion of the Horseshoe Lake and Crab Orchard flocks utilized the Ballard County area, these data for the Ballard County flock have not appeared in the literature.

ACKNOWLEDGMENTS

Special thanks are extended to Mr. F. R. Duley of the Fin and Feather Waterfowl Processing Plant, Oscar, Kentucky, for permission to use facilities and equipment throughout the study. Mr. James Moynahan, Refuge Manager, also provided valuable assistance in completing this study.

METHODS AND MATERIALS

The facilities of a local processing plant were utilized from 22 December 1974 to 11 January 1975 as a data collection point. The sex, age, and weight of a random sample of Canada geese killed by hunters were recorded as they arrived at the plant. The weight of each goose was determined to the nearest ounce and then converted to grams. Sex and age characteristics were made following the plumage and cloacal characteristics described by Hanson (1967) with 1 modification. Only 2 age classifications were used; all geese less than 8 months old were considered immatures and those older than 8 months were considered adults.

Of the geese presented at the processing plant, it was apparent that at least 2 races of Canada geese utilized the area. Three specimens of Hutchins Canada goose *B. c. hutchinsi* and 500 specimens of Todds Canada goose *B. c. interior* were examined and weighed. The 3 Hutchins geese included 1 male 1,984 g (4.37 lb) and 2 females 1,550 g (4.44 lb) and 1,786 g (3.94 lb).

TABLE 1.—WEIGHTS (G) OF 500 *B. C. INTERIOR* ARRANGED ACCORDING TO SEX AND AGE GROUPS, BALLARD COUNTY, KENTUCKY. SE = STANDARD ERROR OF THE MEAN, SD = STANDARD DEVIATION

	No.	%	Weight	Mean	SE	SD
Males						
Immatures	177	35.4	2,381–4,224	3,498	24	316
Adults	82	16.4	2,778–5,585	4,084	50	456
Females						
Immatures	185	37.0	2,353–4,560	3,059	26	350
Adults	56	11.2	2,636–4,933	3,532	59	442
All immatures	362	72.4	2,353–4,560	3,274	21	399
All adults	138	27.6	2,636–5,585	3,860	45	525
All males	259	51.8	2,381–5,585	3,684	28	456
All females	241	48.2	2,353–4,933	2,169	27	423
Total	500	100.0	2,353–5,585	3,436	23	510

The data for these 3 geese are not included in the rest of the computations.

RESULTS

The entire sample (Table 1) had a weight range of 2,353–5,585 g (5.19–12.31 lb) with a mean of 3,435 g (7.57 lb). Analyses of variance (F-test) demonstrated that the weight differences between males 3,683 g (8.12 lb) and females 3,169 g (6.99 lb) and between immatures 3,274 g (7.22 lb) and adults 3,860 g (8.51 lb) were highly significant ($P = 0.01$). Males averaged heavier than females and immatures averaged lighter than adults. The interaction of sex and age with weights was not significantly different.

Several individuals were exceptionally large and their weights are worth noting. Twelve geese weighed more than 4,537 g (10 lb) each. Of these, 1 immature female weighed 4,560 g (10.05 lb) and 2 adult males weighed 5,273 g (11.62 lb) and 5,585 g (12.31 lb), respectively.

The population had a sex ratio of 107.5 males/100 females and an age ratio of 262.3 immatures/100 adults. Males (51.8%) were slightly more abundant than females (48.2%) and immatures (72.4%) were more numerous than adults (27.6%).

Of the total population, immature females (37.0%) were slightly more numerous than immature males (35.4%) and adult females (11.2%) were less numerous than adult males (16.4%).

DISCUSSION

The population mean for the Ballard County flock falls between the overall means of 3,217 g (7.09 lb) and 3,615 g (7.97 lb) for the 2 Michigan flocks, respectively, reported by Rudersdorf (unpublished doctoral dissertation) and Friley (1960). Also, the Ballard goose weights averaged between 49 g (0.11 lb) lower and 253 g (0.56 lb) higher than the southern Illinois flock studied by Elder (1946) in December and between 39 g (0.09 lb) lower and 45.1 g (0.10 lb) higher in January.

It is difficult to compare the weights of the Ballard geese with those of the Crab Orchard flock (Raveling 1968) and the Horseshoe Lake flock (Hanson 1965) except for immatures, yearlings, and adults, since this study distinguished only between immatures and adults. However, Ballard County immature males and immature females were lighter than those in the Crab Orchard flock in November–December by 63 g (0.14 lb) and 144 g (0.32 lb), respectively, and lighter than the Horseshoe Lake flock in December by 12 g (0.03 lb)

and 177 g (0.26 lb), respectively. Ballard County adult males and females were lighter than those in the Crab Orchard flock in November–December by 41 g (0.09 lb) and 111 g (0.24 lb), respectively, and ranged 29 g (0.06 lb) lower to 15 g (0.03 lb) higher, respectively, than Hanson's Horseshoe Lake flock in December. There was very little difference in weight between the Ballard County adult geese and the 2 Illinois flocks. However, if the Ballard County flock had been separated into yearlings and adults, as were the 2 Illinois flocks of Raveling (1968) and Hanson (1965), the differences might have been more significant.

Twelve of the 500 geese from Ballard County weighed more than 4,536 g (10 lb). In 1946, Elder found 6 of 2,179 geese that weighed more than 4,536 g (10 lb). Three of the largest geese are especially worth noting because they may have been examples of *B. c. maxima.* For their respective age and sex categories, no geese examined by Elder were as large as the immature female 4,560 g (10.05 lb) and the 2 adult males 5,273 g (11.62 lb) and 5,585 g (12.31 lb) from Ballard County. Nor were any geese this large reported by Raveling (1968), who made special attempts to exclude the greater Canada goose from his sample.

No factors other than weights (namely, culmen, and tarsus lengths) were noted for these larger geese except for age and sex.

The immature female was 22 g (0.05 lb) heavier than the 4,536 g (10 lb) recommended minimum weight necessary for immature females as selective breeding stock in a flock of greater Canada geese (Dill and Lee 1970). This immature goose was also heavier than 2 immature greater Canada geese, each weighing 4,479 g (9.88 lb) reported by McWhorter and Bossenmaier (Hanson 1965). The 5,585 g (12.31 lb) adult male was 589 g (1.3 lb) heavier than the 4,989 g (11 lb) recommended as the minimum weight for adult males necessary to retain a flock of greater Canada geese (Dill and Lee 1970). This goose was also heavier than an adult male reported by Schoonover in Hanson (1965) that weighed 5,159 g (11.38 lb). More detailed studies are needed to determine whether the larger individuals from Ballard County were just larger and healthier specimens of Todds goose or smaller specimens of the giant Canada goose.

The sex ratio (107.5 males/100 females) is not significantly different from the theoretical and expected 50:50 ratio. This agrees closely with Friley (1960) who found a 4-year ratio of 110.3 males/100 females in a Michigan flock. It also agrees with data reported by Rudersdorf (unpublished doctoral dissertation) who determined that the Chi-square value was not significant for his population of 286 males and 249 females.

The age ratio of 262.3 immatures/100 adults is higher than that reported by Friley (1960) who found a 5-year mean of 87.6 immatures/100 adults. His extremes were 58.4 immatures and 119.8 immatures/100 adults.

LITERATURE CITED

DILL, H. H., AND F. B. LEE (Eds.). 1970. Home grown honkers. Int. Wild Waterfowl Ass. Jamestown, No. Dak. 154 pp.

ELDER, W. H. 1946. Age and sex criteria and weights of Canada geese. J. Wildl. Manage. 10(2):93–111.

FRILEY, C. E. 1960. The Canada geese of Michigan's swan creek highbanks, 1953–1957. J. Wildl. Manage. 24(1):97–99.

HANSON, H. C. 1965. The giant Canada goose. Southern Ill. Univ. Press, Carbondale, Ill. 226 pp.

———. 1967. Characters of age, sex, and sexual maturity in Canada geese. Ill. Nat. Hist. Surv. Div. Bull. No. 49 15 pp.

RAVELING, D. G. 1968. Weights of *Branta canadensis interior* during winter. J. Wildl. Manage. 32(2):412–414.

A New Application in the Pitfall Trapping of Insects

BURTON J. SMITH[1]
Department of Biology, Western Kentucky University,
Bowling Green, Kentucky 42101

ABSTRACT

A previously untested technique in pitfall trapping utilized various drift fence designs to funnel insects into the trap. The use of these designs resulted in increased efficiency of catch severalfold over a similar unfenced trap. The use of these designs to investigate migratory patterns of ground insects appears to have considerable promise.

INTRODUCTION

The use of pitfall traps as a sampling device has been known for some time. There are numerous variations in the construction of such traps, from glass jars to gallon cans. Fichter (1941) described a design that incorporated a rain shield over a 2-story trap with partitions in the upper story to guide insects into the lower story that contained alcohol. Since then, most work with pitfall traps has been concentrated on using different kinds of baits, ways of positioning traps (Greenslade 1964), and various time-sorting techniques (Williams 1958, Holthaus and Riechert 1966).

The concept of using a funnel-shaped device for concentrating and leading animals into traps is common practice in the sciences and on many western ranches (wing corrals, drift fences, etc.). However, the application to ground insects appears unique. During the summer of 1975, I combined the pitfall trap with a winged V drift fence specifically for the purpose of collecting insects.

MATERIALS AND METHODS

The study area was an abandoned tobacco field, 10 miles (16.1 km) south of Bowling Green, Kentucky. The field was last cultivated in 1974 and had been undisturbed since then. The predominant vegetation was ragweed with scatterings of Bermuda grass, goldenrod, and various other forbs. There was some ground litter, but bare ground was evident in many places. The field was about 2 acres (0.8 ha) in size, with the long axis in an east–west direction.

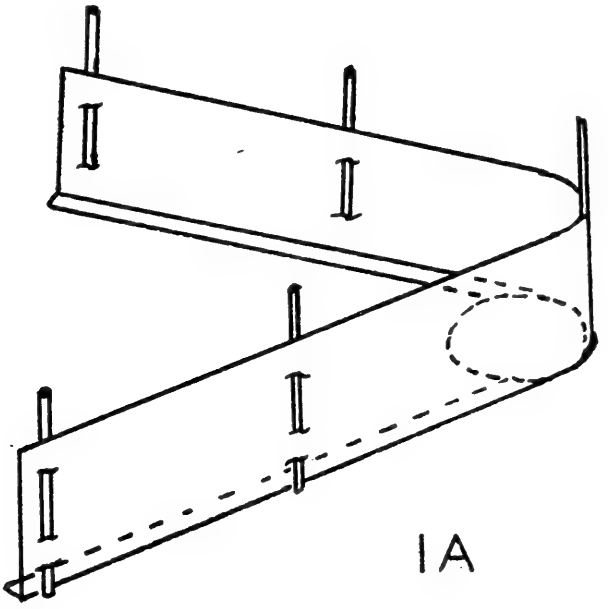
The traps were gallon (3.8-liter) cans, 15.5 cm in diameter, buried slightly below ground level and filled with water to a depth of 5 cm. Fences were constructed of strips of plastic trash bags about 10 cm high and about 1 m long (Fig. 1A). Small sticks were used to hold the plastic in place.

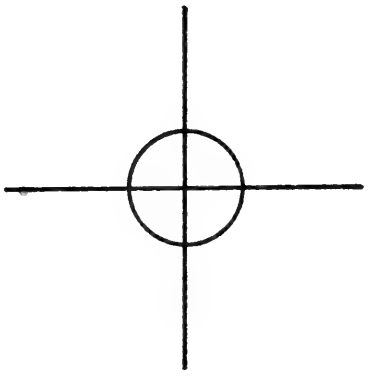
The experiment was initiated on 21 August 1975 and terminated on 7 October 1975, and was divided into 5 phases based on design of wing fences and layout of traps. Thirty-three collections, each of 24-hour duration, were made during the study. The experiment was interrupted several times by heavy rains. However, all but Phase IV were run on consecutive days.

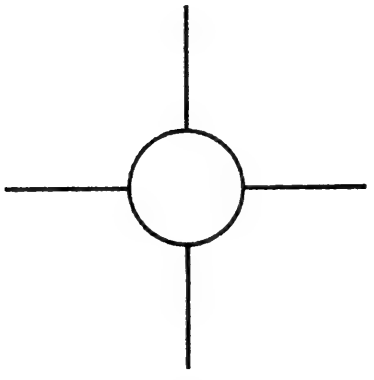
Phase I involved 12 traps, 6 open and 6 with cross fence design (Fig. 1B, 1C, 1D). The traps with a cross fence design had plastic across the top of the can at the point of intersection. Each arm of the cross was 0.5 m long. Those traps were laid out in a line in an east–west direction, about 10 m from the north side of the field. The fenced and unfenced traps were spaced 2.5 m apart. This phase continued for 5 days.

Phase II consisted of 12 traps, 4 with no fence and 8 with a V design. Four V traps had the opening to the north and 4 to the south. Each arm of the V was 1 m long with an angle of about 60° between them. Those traps were laid in a straight line

[1] Present address: Route 2, Box 176, Interlachen, Florida 32048.







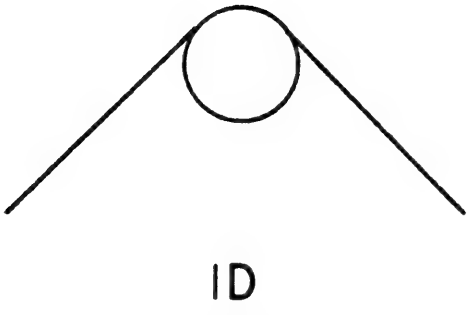


FIG. 1. Various fence designs for pitfall traps. 1A, position of plastic and supporting sticks on V wing fence. 1B, Phase I cross fence. 1C, Phase V cross fence. 1D, V wing fence.

TABLE 1.—NUMBERS OF GRYLLIDAE AND CARABIDAE CAUGHT IN PITFALL TRAPS DURING EACH PHASE OF THE STUDY. N, E, S, AND W INDICATE DIRECTION IN WHICH THE TRAP FACED. SEE TEXT FOR EXPLANATION

	Gryllidae	Carabidae	Total
Phase I, 5-day collection			
Fence	56	80	136
Open	61	55	116
Total	117	135	252
Phase II, 6-day collection			
S	90	92	182
N	156	171	327
Open	44	38	82
Total	290	301	591
Phase III, 9-day collection			
N	148	250	398
E	201	160	361
W	123	141	264
S	104	96	200
Total	576	647	1,223
Phase IV, 6-day collection			
N	69	191	260
E	87	166	253
W	92	164	256
S	46	159	205
Open	51	30	81
Total	345	710	1,055
Phase V, 7-day collection[1]			
N	16	38.7	
E	22	35.3	
W	30.7	41.7	
S	20	48.7	
Open	14	8.5	
Cross	144	111	255
Total	438	621	1,059

[1] These data are averages per trap for 7 days, totals are for all traps during the 7 days.

with the V designs alternating with open traps with the same location and distances as in Phase I. The duration of this phase was 6 days.

Phase III consisted of 12 traps, all with the V design. This layout was an L configuration with one arm pointing south and the other west. The traps on the north–south arm were set so that the V opened east and west in alternating fashion. The east–west arm was similar with the traps opening to the north or south. This phase lasted 7 days.

Phase IV was conducted on the side of the field opposite from Phase I and was set back from the edge about 10 m. Twelve traps were arranged in an L configuration similar to Phase III except that one arm pointed north and the other south. Three open traps (no fences) were set off the apex of the L and ran in a southeasterly direction. The V traps were similar to the above except that the angle was 90°. This phase lasted for 6 nonconsecutive days due to heavy rains.

Phase V was identical with Phase IV except that the center open trap was fitted with a modified cross. That cross differed from that in Phase I in that each arm was 1 m long and the fence did not cross the trap but terminated at the edge of the can. This phase continued for 7 days.

RESULTS AND DISCUSSION

There were 6,259 insects caught during the experiment. Of those, 4,180 were either Carabidae or Gryllidae, and only those families are discussed. The balance consisted of small numbers of many families. Data from each phase are presented in Table 1. A greater number of carabids were caught with the cross fence than with the unfenced traps during Phase I. There was a slightly opposite trend with the gryllids, thought to have resulted from the fence extending across the pit, thereby acting as a bridge and reducing the open area of the trap.

The data from Phase II show a definite increase in the numbers caught in the south-facing and north-facing fenced traps over the open traps. Also, the north-facing traps caught almost twice as many insects as the south-facing ones. This suggested the possibility of some sort of mass directional movement.

Phase III was set up to further investigate the possibility of detecting any mass movement, and the data indicated a continuous north to south movement for both groups of insects.

Phase IV was interrupted twice by heavy rains which might have had some influence on the results, e.g., the average catch per

trap per day dropped from 5.3 insects in Phase III to 4.6 in Phase IV. The fenced cans were more efficient than the open cans, notably in the capture of carabids. Again, movement patterns were east–west for the gryllids and to the south for the carabids. The increased catches reported for the various directions were, in general, consistent on a day-to-day basis for all phases of the experiment.

Phase V was an effort to clarify the reasons for the increased catches in the fenced traps over the open ones. There were 3 traps that opened toward each of the 4 cardinal directions, along with 2 open traps and 1 with a cross configuration. Because of the different numbers of traps for each unit, the average numbers of insects caught per trap every 7 days was used for comparison.

As can be noted from the data in Table 1, the fenced traps consistently caught more insects than the unfenced ones. Combining the data for both families, the actual increase ranged from 1.2 times more than the unfenced trap in Phase I to 11.3 times for the cross fence trap in Phase V. The V traps caught from 2.4 to 3.2 times more than the unfenced traps. If the average value for the V traps is taken as 2.8 and multiplied by 4 (since the V trap is open only to 1 quadrant), the answer is 11.2, quite close to the 11.3 for all 4 quadrants.

Combining the results for the Gryllidae and the Carabidae in Phase V, 253 were caught per trap for the 7 days. That total was arrived at by summing the catch of all V traps for the 7-day period and dividing by 3, giving a composite number that represents the catch from the 4 different directions. The cross fence trap caught 255 insects for the same period. The similarity of those numbers imply that 4 traps that represent the 4 quadrants of the compass caught as much as a single cross type trap. There appears to be very little loss of insects once they enter the V fenced area when compared to the cross fence trap. It is suggested that the insects act similarly to a particle striking a smooth surface and rebounding off it. The probability of catch for any particular insect that arrives at the trap is enhanced by each encounter with the fence.

Considerably more work is needed to verify these results, but I believe they do indicate some intriguing trends which, if verified, could lead to a method of quantifying samples as well as determining rates and directional movements of ground dwelling insects.

LITERATURE CITED

FICHTER, E. 1941. Apparatus for the comparison of soil surface arthropod populations. Ecology 22:338–339.

GREENSLADE, P. J. M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J. Anim. Ecol. 33:301–310.

HOLTHAUS, W. A., AND S. E. RIECHERT. 1966. A new time-sort pitfall trap. Bibl. Entomol. Soc. Amer. Ann. 66:1362–1364.

WILLIAMS, G. 1958. Mechanical time-sorting of pitfall captures. J. Anim. Ecol. 27:26–35.

Eye Lens Weight as an Age Indicator of White-tailed Deer in Central Kentucky

Carl J. Keller
Department of Biological Sciences, Eastern Kentucky University,
Richmond, Kentucky 40475
and
Larry M. Landry
Department of Mathematics, Eastern Kentucky University,
Richmond, Kentucky 40475

Abstract

Although a wildlife population is a dynamic entity, knowledge of age and sex structure provides an indicator to population composition in a particular locality. This report presents a study of age determination of the white-tailed deer population at the Blue Grass Army Depot in central Kentucky. The aging method used incorporated the dry eye lens weight technique and the principal objective was to determine a regression formula for the relationship of eye lens weight to age. The best formula found from available data was $A = (1.7357 \times 10^{-7}) \times W^{3.0544}$, where A is the age of deer and W is the eye lens weight. This model explained 91 percent variability and visually appears to present a good overall fit.

Introduction

Perhaps the most powerful tool of the wildlife investigator is understanding the age and sex structure of a population. This permits determination of breeding males and females, the number of young of the year, the number of yearlings, and possibly post reproductive adults. Thus, the reproduction and survival of a wildlife population lends information of fundamental importance to population dynamics.

One recommended method of aging white-tailed deer is by means of tooth eruption and tooth wear which gives reasonably accurate results. However, that technique lacks the accuracy favored for aging purposes (Downing and Whittington 1966). In his pioneer study of eye lens weights in the cottontail rabbit, Lord (1959) effectively introduced an improved aging technique, and subsequent investigators have employed that method for a variety of wildlife species (Beale 1962, Campbell and Tomlinson 1962, Payne 1961, and Sanderson 1961).

The first qualitative observations on the measurements of the eye were by the French ophthalmologist du Petit who reported on lens weights in the second decade of the eighteenth century (Friend 1967). Detailed reports on the topic were first documented by Smith (1883) who reviewed the information on lens growth to that time. In one of his reports, Smith elaborated upon the physical–biological properties of human eye lenses and concluded that the growth of the lens does not cease with the rest of the body, but is continuous throughout life. Researchers that followed made efforts to support Smith's conclusions, and the concept is currently being applied to birds and mammals. The significance of this technique is that it determines age more accurately than other methods; hence, it is highly regarded among wildlife population analysts. The present study reports the relationship of the dry lens weight to age among white-tailed deer *Odocoileus virginianus* in central Kentucky by use of regression analysis, and also attempts to further strengthen this technique as a means of population analysis.

ACKNOWLEDGMENTS

We express our appreciation to the students of the Fall 1974 wildlife techniques class at Eastern Kentucky University who assisted in field collection of data, and to Mr. Robert Craig who assisted in computerization of the data. Many thanks are extended to Dr. Ward J. Rudersdorf for his assistance and encouragement during this study. Acknowledgment must also be given to Dr. Donald Batch and Mr. Gary Shockley for critically reviewing the manuscript.

METHODS AND MATERIALS

The present aging study basically follows that described by Kolenosky and Miller (1962), Longhurst (1964), and Lord (1959). A total of 326 white-tailed deer eyes were collected on 9, 10, 23, and 24 November 1974 during a split hunting season at the Blue Grass Army Depot in central Kentucky. Care was exercised in removal of the eyes so as not to traumatize the lenses. Small curved scissors and a short hemostat clamp were used to sever extraocular muscles, the optic nerve, and posterior fascia in removal of the eyeballs.

Each deer was assigned to an estimated age group by methods of tooth eruption and wear (Severinghaus 1949), and pertinent data were assigned to each collected eye before fixing in 10 percent formaldehyde solution. Friend (1968) suggested that the fixative solution be used to eliminate autolysis, to prevent necrosis from bacterial action, and to harden the lens in order to reduce damage in further handling. Friend also pointed out that formaldehyde acts as a protein fixative which proves most appropriate in this case, since approximately 95 percent of the dry weight of the lens is protein. Some experimenters (Connolly 1969, Downing and Whittington 1966) allowed the eyes they studied to remain in solution for as long as 6 months, perhaps so that the hardened lens would allow easier handling and fewer sources of error. Before fixing, each eyeball was tagged with appropriate data tied to the optic nerve, although Downing and Whittington (1966) suggested the use of clip-on alteration tags to save time.

Eyes were allowed to remain in formaldehyde for 9 weeks before removal of the lenses. First, the limbus area was punctured with a pointed scalpel and an incision was made approximately three-fourths around the corneal periphery. After lifting the corneal flap, the iris was carefully slit transversely and the lens extracted.

Small Coors crucibles were used to retain individual lenses while drying in a precision oven at 80 C for 2 weeks. Lenses were allowed to cool at room temperature 3 to 5 min before weighing, because this cooling permitted reduction of convection currents as indicated by Longhurst (1964). Lenses were weighed and recorded to the nearest 0.1 mg on an analytical balance. After weighing the lenses, the lens weights and the ages of the deer as ascertained by the dentition method were recorded. The regression equation for the relationship of the population ages to eye lens weights was obtained.

The primary goal of regression analysis is to obtain predictions of one variable using the known values of another. In the case of simple linear regression, these predictions are made by means of an equation of the form $Y = a + bX$ where a is the intercept and b is the slope of a straight line. This line used to describe the relationship between X and Y is generally obtained from sample data. Utilizing the theory of least squares, a is found to be $\overline{Y} - b\overline{X}$ and

$$b = \frac{\sum_{1}^{n} (X - \overline{X})(Y - \overline{Y})}{\sum_{1}^{n} (X - \overline{X})^2}$$

for the regression of Y on X, where n is the number of observations, $\overline{Y}$ and $\overline{X}$ are the arithmetic averages of the dependent and independent variables, respectively. The intercept a, as given, can be interpreted as the point where the estimated regression line crosses the Y axis in the usual cartesian coordinate plane. It is

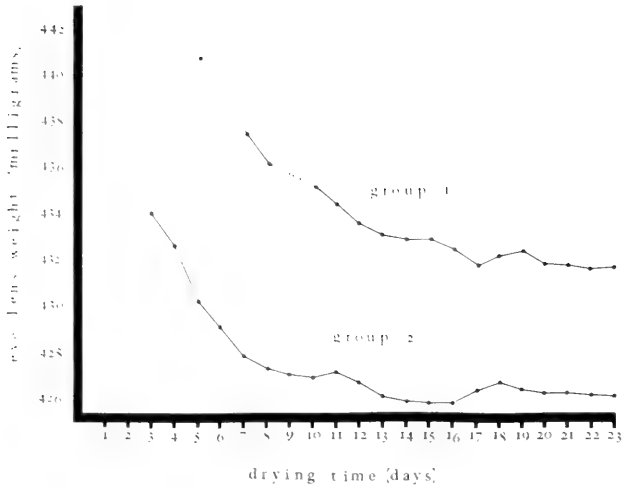


FIG. 1. Rates of oven drying of eye lenses of white-tailed deer at 80 C. Each group indicates average values of 10 randomly chosen lenses.

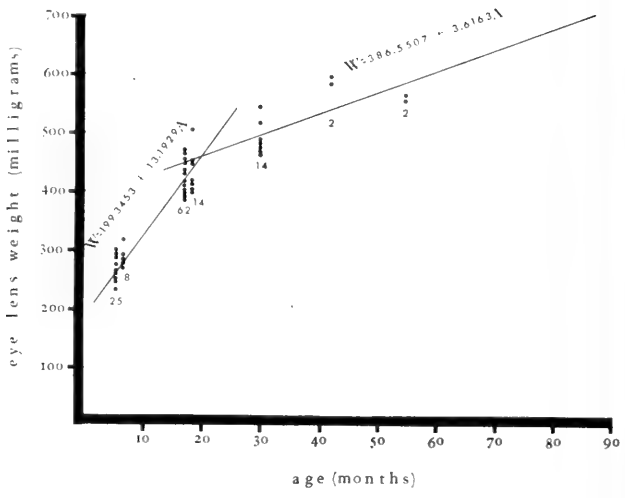


FIG. 2. Regression lines for 2 categories of data on male white-tailed deer. Numbers assigned to respective age groups indicate actual sample sizes.

noted that this value is obtained by adjusting the average of the dependent variable values (Y's) for the slope and the average of the known values. The slope is obtained from the sample data by summing the products of the deviations from the means of the paired observations relative to the sum of squared deviations from the mean of the known values (X's).

However, it is emphasized here that a straight line is not always an appropriate function for relating Y to X. Polynomial functions, exponential functions, and logarithmic functions are usual examples of nonlinear relationships between variables. A quadratic equation of the form $y = a + bx + cx^2$, an exponential function of the form $y = ae^{-bx}$, and a logarithmic function of the form $y = a + b \log X$ are illustrations of the examples mentioned above. The method of least squares is extended in the case of the quadratic to obtain the formulas from which a, b, and c may be obtained using the data points. A function of the form $Z = kw^b$ upon taking logarithms is $\log Z = \log k + b \log X$ or $y = a + b \log X$ where $a = \log k$, $y = \log Z$, and $X = W$. This logarithmic transformation allows the use of simple linear regression techniques for these data. Conversion back to its original form becomes, $A = kw^b$, where A represents age, w represents weight of eye lens, and k and b are regression constants.

The transformation of the data to logarithms, the determination of the "best-fitting" regression equation, and the transformation back to original form were all done with computers.

RESULTS

Friend (1968) indicated that eye lenses were considered dry when an additional drying period produced no significant reduction in weight. Various workers have employed different drying temperatures and drying periods depending on the size of the lens (Kolenosky and Miller 1962, Longhurst 1964). During the present study an attempt was made to determine the rate of desiccation and the time of adequate stabilization of white-tailed deer eye lenses. Average values of 2 groups of deer lenses with each group having 10 randomly chosen samples are shown in Fig. 1. Periodically, each group was weighed, usually midday, and a progressive decline in weight loss was recorded throughout the drying period. Satisfactory weight stabilization in Group 1 was established by the fourteenth day followed by less than 0.4 percent reduction in weight throughout the remainder of that drying period. Group

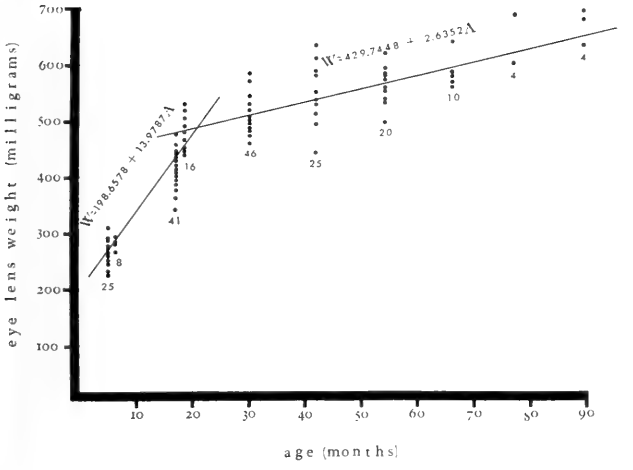


FIG. 3. Regression lines for 2 categories of data on female white-tailed deer. Numbers assigned to respective age groups indicate actual sample sizes.

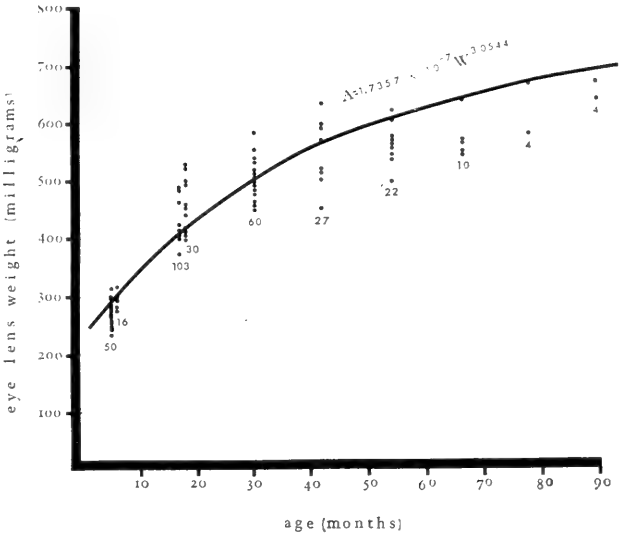


FIG. 4. Mathematical model for predicting age from lens weight in white-tailed deer. A = age, W = dry weight of lens. Numbers assigned to respective age groups indicate actual sample sizes.

2 also illustrated weight stabilization around the fourteenth day with only slight weight reduction thereafter. Therefore, a 2-week drying period was considered adequate for lenses of white-tailed deer. Shorter drying periods at 80 C have been successfully employed (Longhurst 1964); however, the main concern with any dry lens study is treating all sample lenses in the same manner.

Even though the final form of the model does a reasonable job in depicting the variability of the data, it is tempting to break up the age groups into 2 categories before applying the regression analysis. One category suggested by the observed data is 2 years and younger, and the other is 2.5–7.5 years of age. A straight line was fit to both categories for both male and female data (Figs. 2, 3). An attempt was then made to discern differences between males and females, but inadequate sample sizes for older age groups, particularly males, made it difficult to apply a reliable statistical test. The probable reason for lack of data among older males is that most hunters did not wish to relinquish antlered bucks. In the younger age category, the regression lines for bucks and does differed insignificantly.

It would be difficult to assign specific gender to random eye lenses up to 2 years of age. Assuming this is also true in the upper age category (Figs. 2, 3), the data for males and females were combined. Applying simple linear regression to the categories of male and female data, the results are: the regression line for white-tailed deer 2 years and under is $W = c + bA = 199.2482 + 13.5299$ A, and for deer 2.5–7.5 years is $W' = 428.2967 + 2.6289$ A'. Eighty-eight percent of the variability in the data was explained by the second line. Therefore, a straightforward linear regression was fit to all data. This model proved to be ineffective since the residuals showed a pattern of minuses, followed by pluses, followed again by minuses. Furthermore, only 72 percent of the total variability was due to the regression.

Hence, this leads one to a regression curve of the type $A = KW^b$ for predicting age from eye lens weight in white-tailed deer. Using the accumulated data, the regression equation is $A = (1.7357 \times 10^{-7}) W^{3.0544}$ or in terms of the regression of weight on available ages, $W = 163.4557 A^{.3274}$. It is noted here that the logarithmic transformation yielded the equations, $\log A = -5.7606 + 3.0544 \log W$ and $\log W = 2.2134 + .3274 \log A$ which when transformed back to the original form for the

data resulted in the exponential equations mentioned above.

Observation of this model appears to present a good overall fit to the eye lens weights. Approximately 91 percent of the variability is explained by this exponential curve, and the residuals appear uniformly distributed about the curve. This model may be used for further deer lens studies as an age indicator in Kentucky.

LITERATURE CITED

BEALE, D. M. 1962. Growth of the eye lens in relation to age in fox squirrels. J. Wildl. Manage. 26(2):208–211.

CAMPBELL, H., AND R. E. TOMLINSON. 1962. Lens weights in chuckar partridges. J. Wildl. Manage. 26(4):407–409.

CONNOLLY, G. E. 1969. The eye lens as an indicator of age in the black-tailed jack rabbit. J. Wildl. Manage. 33(1):159–164.

DOWNING, R. L., AND R. W. WHITTINGTON. 1966. Eye lens weights–valuable deer management tools. Proc. Southeast. Ass. Game Fish Comm. 18:17–20.

FRIEND, M. 1967. A review of research concerning eye-lens weight as a criterion of age in animals. N. Y. Fish Game. J. 14(2):152–165.

———. 1968. The lens technique. Trans. N. Amer. Wildl. Nat. Res. Conf. 23:279–298.

KOLENOSKY, G. B., AND S. MILLER. 1962. Growth of the lens of the pronghorn antelope. J. Wildl. Manage. 26(1):112–113.

LONGHURST, W. M. 1964. Evaluation of the eye lens technique for aging Columbian black-tailed deer. J. Wildl. Manage. 28(4):773–784.

LORD, R. D., JR. 1959. The lens as an indicator of age in cottontail rabbits. J. Wildl. Manage. 23(3):358–360.

PAYNE, R. B. 1961. Growth rate of the lens of the eye of house sparrows. Condor 63(4): 338–340.

SANDERSON, G. C. 1961. The lens as an indicator of age in the racoon. Amer. Midl. Nat. 65 (2):481–485.

SEVERINGHAUS, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13(2):195–216.

SMITH, P. 1883. Diseases of crystalline lens and capsule. I. On the growth of the crystalline lens. Trans. Ophthal. Soc. Unit. King. 3: 79–99.

Sighting of an Eastern Spotted Skunk in Henderson County, Kentucky

Gary H. Richins and Richard D. Panke
Dames & Moore, 1150 West Eighth Street,
Cincinnati, Ohio 45203

Abstract

A single eastern spotted skunk was sighted by the authors in Henderson County, Kentucky. This is the only authenticated sighting of this species in western Kentucky.

The eastern spotted skunk *Spilogale putorius*, though nowhere abundant, is common to the southern United States. At one time, however, its range may have been much greater. Indeed, Van Gelder (1959) suggested that the species' former range may have included southern Illinois and Indiana, based on the discovery of spotted skunk remains in Indian middens in Illinois. Van Gelder (1959) further suggested that spotted skunks are spreading northward, either as a response to a general warming trend in global temperatures or by opportunistic occupation of man's rural habitations which provide a broader base of suitable habitat and a relatively constant supply of food and shelter.

In Kentucky, specimens of *S. putorius* are known only from Bell, Elliott, and McCreary counties (Barbour and Davis 1974). However, for a number of years there have been reported but unauthenticated sightings of spotted skunks by local residents in western Kentucky. Enough such sightings have been reported that Barbour and Davis (1974) suggested that scientists working in western Kentucky be on the lookout for *S. putorius*.

While conducting part of an environmental inventory of Henderson County, Kentucky, on the night of 4 October 1974, we sighted a single *S. putorius* which crossed the road in front of our vehicle. The animal was illuminated for about 20 sec by 2 200,000 candlepower (2.5×10^6 lumens) spotlights handheld by us. This observation, believed to be the first authenticated sighting of *S. putorius* in western Kentucky, occurred in agricultural land near Kentucky Highway 359 about 2 miles (3.2 km) southwest of Smith Mills in Henderson County.

There is little doubt of the authenticity of this sighting; the spotted pelage, the smaller size, and the distinctive gait preclude its being mistaken for a striped skunk *Mephitis mephitis*. Furthermore, the senior author has previously observed spotted skunks in Utah and Arizona on several occasions, and the junior author has observed them in Florida.

We feel that workers in western Kentucky should anticipate additional sightings of *S. putorius*. With additional information about its presence in Kentucky, the true range and status of the spotted skunk can be determined.

We express our thanks and appreciation to the Texas Gas Transmission Corporation for supporting the study that led to this observation.

Literature Cited

Barbour, R. W., and W. H. Davis. 1974. Mammals of Kentucky. University Press of Kentucky, Lexington, Ky. 322 pp.

Van Gelder, R. G. 1959. A taxonomic revision of the spotted skunk (genus *Spilogale*). Bull. Amer. Mus. Nat. Hist. 117:233–392.

Cold Treatment and Budbursting in Sweet Gum from South-central Kentucky

W. R. Randel[1] and Joe E. Winstead
Department of Biology, Western Kentucky University,
Bowling Green, Kentucky 42101

Abstract

Twigs of *Liquidambar styraciflua* with dormant buds showed an inverse relationship in length of time for budbursting at warm temperatures in respect to length of time of prior cold treatment. Stem samples exposed to cold weather in nature and twigs given cold treatment in the laboratory gave a similar response when placed under test conditions in growth chambers.

Introduction

Numerous studies have been conducted on the physiological and phenological patterns of hardwood trees important in the United States, but there is little such information on populations within Kentucky. As part of our investigations on sweet gum, *Liquidambar styraciflua*, we decided to determine the patterns of budbursting in relation to cold treatment or exposure to cold and subsequent introduction to environmental conditions that would stimulate growth. Previous work on sweet gum in our laboratory (Winstead 1975, Randel and Winstead 1976) and elsewhere (Williams and McMillan 1971a, 1971b) have shown that this species lends itself well to laboratory investigations. As one of the most important hardwood species in the United States and in Kentucky, in-depth studies of growth factors are needed to properly determine its management and propagation.

Materials and Methods

Stem sections with naturally dormant buds were taken from trees in December 1973 in 2 areas in south-central Kentucky. The 2 collection sites, though not greatly separated by latitude, represent 2 distinct habitats approximately 48 km apart. The more northern site near Morgantown in Butler County, 37°14′N, is in the Hill Section of the Western Mesophytic Forest (Braun 1950). In contrast, the southern site close to Alvaton in Warren County, 36°52′N, is in the Mississippi Plateau Section of the Western Mesophytic Forest. Stem sections from 4 trees at the southern site and 3 at the northern site were tested for the amount of cold treatment required for budburst. Lengths of stems were cut to 8 cm and set in water before placing in a cold chamber at 4 C. At regular intervals, 10 stems from each tree were removed from the cold chamber and placed in a growth chamber with a day–night temperature of 32–24 C (each temperature regime of 12-hour duration) and a 15-hour photoperiod. Ten stem sections approximately 8 cm long were also collected periodically during the winter from each of 4 trees of Warren County and placed directly into the growth chamber. Each stem section tested had a terminal bud and lateral buds along the stem.

After being placed in the growth chamber, the buds of the stem sections were examined daily for signs of budbursting. A twig was scored as having budburst when either the terminal bud or a lateral bud showed leaf emergence.

Monthly reports of the National Oceanic and Atmospheric Administration, Environmental Data Service, Ashville, North Carolina, provided data on the number of days in the area of the southern collection site when the temperature dropped below 4 C.

[1] Present address: Math and Science Division, Garland County Community College, Hot Springs, Arkansas 71901.

TABLE 1.—TIME REQUIRED FOR FIELD COLLECTED TWIGS STORED AT 4 C TO EXHIBIT BUDBURST UNDER CONTROLLED CONDITIONS

Number of days at 4 C	Average number of days at 32–24 C for budburst	Percentage of twigs surviving to budburst
Warren County Collection Site		
0	65	28
14	45	23
30	33	30
44	27	17
54	28	23
66	20	7
Butler County Collection Site		
12	38	23
28	26	17
42	20	27
52	24	17
64	23	7

TABLE 2.—TIME REQUIRED FOR TWIGS RECEIVING COLD TREATMENT IN THE FIELD TO EXHIBIT BUDBURST UNDER CONTROLLED CONDITIONS

Number of days below 4 C	Average number of days at 32–24 C for budburst	Percentage of twigs surviving to burst
12	56	13
39	25	37
46	20	10
69	22	27

RESULTS AND DISCUSSION

Buds collected in the field, brought into the laboratory, and stored for a specific time at 4 C showed a cold temperature requirement for budbursting. The time required for budbursting under the 32–24 C, 15-hour photoperiod test condition was inversely proportional to the amount of time spent at 4 C for both the northern and southern collections sites (Table 1). There was a high mortality rate of the twigs as indicated in Table 1 thus the actual number of twigs living to exhibit budburst from each set ranged from 3 to 12.

Twigs collected periodically, brought into the laboratory from the field, and placed directly into the 32–24 C, 15-hour photoperiod test condition showed the same response as the buds receiving cold treatment in the laboratory (Table 2). Again, survival of twigs before time of budburst was low with a range of from 4 to 15 twigs remaining viable in each test set.

Among phenological characteristics that provide populational adaptations to a given habitat, budbursting has been shown to have a geographic correlation in sweet gum (Winstead 1968 unpublished doctoral dissertation, University of Texas, Austin, Texas), but detailed studies of specific populations are lacking. Since spring temperatures probably determine the earliest times of budbursting, species with a cold requirement are provided a protective mechanism against initiating growth too soon. In south-central Kentucky, the date of the last frost is highly variable. Records from Warren County show the last spring frost in 1971 was on 7 April while in 1972 it was on 26 April. Although the average date of the last frost in the spring is 16 April, freezing temperatures have been recorded in Warren County as late as 1 May in this century. It would appear that the minimum period of 20 days to initiate bud growth upon exposure to the warm temperatures of the growth chambers provides sufficient insurance to cope with the range of variation of spring frosts from the average in the local habitat of the populations tested.

LITERATURE CITED

BRAUN, E. L. 1950. Deciduous Forests of Eastern North America. Hafner Publ. Co., New York, N.Y. 596 pp. 1972 edition.

RANDEL, W.R., AND J. E. WINSTEAD. 1976. Environmental influence on cell and wood characters of *Liquidambar styraciflua* L. Bot. Gaz. 137:37–45.

WILLIAMS, G. J., III., AND C. MCMILLAN. 1971a. Phenology of six United States provenances of *Liquidambar styraciflua* under controlled conditions. Amer. J. Bot. 58:24–31.

————, AND ————. 1971b. Frost tolerance of *Liquidambar styraciflua* L. native to the United States, Mexico and Central America. Can. J. Bot. 49:1151–1558.

WINSTEAD, J. E. 1975. Populational differences in survival patterns of sweetgum. Trans. Ky. Acad. Sci. 36:80–82.

NEWS AND COMMENT

Annual Meeting The Sixty-second Annual Meeting of the Kentucky Academy of Science will be held 19–20 November 1976 in the Physics and Chemistry Building at the University of Kentucky, Lexington. Drs. Ellis V. Brown and William F. Wagner, Department of Chemistry, University of Kentucky, will be the hosts. The Annual Banquet will be held in the Student Center, and will be preceded by a cocktail hour at Alumni House, Rose and Euclid streets. As stated in the Newsletter, all titles for papers must be in the hands of the Sectional Secretaries no later than Monday, 18 October, so that proper arrangements for the program can be made. The names of all Sectional Secretaries are listed on page 53 of the March 1976 issue of the *Transactions*. Make your reservations now!

Earthwatch Scholarship Winners The Earthwatch Scholarship Program was designed to provide opportunities for youth to participate in research expeditions in various disciplines. Earthwatch is a national effort to mobilize citizens to support science. Costs associated with the program are underwritten by foundations, corporations, public agencies, and other participating organizations. Scholarship winners in Kentucky for 1976 are:

Karleene A. Cox
13301 Seatonville Road
Jeffersontown, Kentucky 40299

Colleen Marie Guffen
3405 Mantucket Drive
Lexington, Kentucky 40502

Douglas Edward Hemken
3381 Pimlico Parkway
Lexington, Kentucky 40502

Mary Ann Lehman
3418 Coldstream Court
Lexington, Kentucky 40502

Diane Elaine Lockard
271 Malabu Drive
Lexington, Kentucky 40502

Leo Kendrick Mills
1919 Fawn Drive
Owensboro, Kentucky 42301

Thomas Paul O'Brien
Lawrence Drive
Edgewood, Kentucky 41017

Daniel Burch Patrick
Cynthiana Road
P. O. Box 407
Paris, Kentucky 40361

Alice Clore Stewart
20 Edgemont Road
Maysville, Kentucky 41056

Susan Letitia Teeter
3386 Pimlico Parkway
Lexington, Kentucky 40502

Melanie Suzanne Wickham
9898 Fern Creek Road
Louisville, Kentucky 40291

Wendy Hope Wonderly
3307 Cornwall Drive
Lexington, Kentucky 40503

Bonny Ann Young
Route 1
Turners Station, Kentucky 40075

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Digenetic Trematodes from Kentucky Fishes[1]

JOHN V. ALIFF

Department of Biology, Georgia College, Milledgeville, Georgia 31061

ABSTRACT

In 1971–1972 and 1974, 3,059 fishes, representing 91 species, were taken from major river drainages of Kentucky including the Big Sandy, Licking, Kentucky, Cumberland, Salt, Tennessee, and Green rivers. Twenty-three species of adult digenetic trematodes occurred in 16.5 percent or 538 host fishes representing 40 species. A list of parasites (new host record) includes (fish species in parentheses): Allocreadiidae: *Allocreadium lobatum* (*Notropis whipplei, Rhinichthys atratulus*); *Crepidostomum cooperi*; *C. cornutum* (*Lepomis megalotis*); *C. isostomum* (*Etheostoma blennioides*); Azygiidae: *Leuceruthrus micropteri* (*Lepomis macrochirus, L. megalotis*); *Proterometra macrostoma* (*Ictalurus melas, Noturus gyrinus, Lepomis gulosus, Micropterus dolomieui, M. punctulatus, M. salmoides, Cottus carolinae*); Bucephalidae: *Paurorhynchus hiodontis*; *Rhipidocotyle septpapillata* (*Lepomis megalotis*); *Bucephalopsis* sp.; Cryptogonimidae: *Acetodextra amiuri*; Gorgoderidae: *Phyllodistomum caudatum* (*Hypentelium nigricans, Etheostoma blennioides*); *P. etheostomae* (*Ambloplites rupestris, Etheostoma caeruleum, E. spectabile*); *P. lacustri* (*Noturus flavus*); *P. lysteri* (*Moxostoma macrolepidotum*); *P. nocomis* (*Semotilus atromaculatus*); *P. staffordi*; Lissorchiidae: *Lissorchis attenuatum*; *L. simeri* (*Minytrema melanops*); Macroderoididae: *Alloglossidium corti* (*Micropterus salmoides*); Opecoelidae: *Plagioporus cooperi* (*Pimephales notatus, P. promelas*); *P. serotinus* (*Pimephales notatus*); *P. sinitsini* (*Campostoma anomalum, Notropis ardens, Moxostoma anisurum, N. chrysocephalus, N. rubellus, N. whipplei, Pimephales notatus, Rhinichthys atratulus, Hypentelium nigricans, Gambusia affinis*); *Podocotyle boleosomi* (*Etheostoma blennioides, E. caeruleum, E. flabellare, E. spectabile*); and Paramphistomatidae: *Pisciamphistoma stunkardi* (*Lepomis megalotis, Etheostoma blennioides*).

INTRODUCTION

The sparsity of records of trematode fauna from Kentucky presents an imperative for this and future studies. Cable (1935) described larval trematode cercariae from Madison County, Harley and Keefe (1971) reported *Crepidostomum cooperi* from *Lepomis* spp. in Madison County, Patton (1973) recovered *Leuceruthrus micropteri* from *Micropterus* spp. in Fayette County, and recent studies by White (1974) recorded *Plagioporus serotinus* from *Catostomus commersoni* in the Kentucky River drainage.

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[1] From a dissertation submitted to the Graduate School, University of Kentucky, Lexington, Kentucky, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

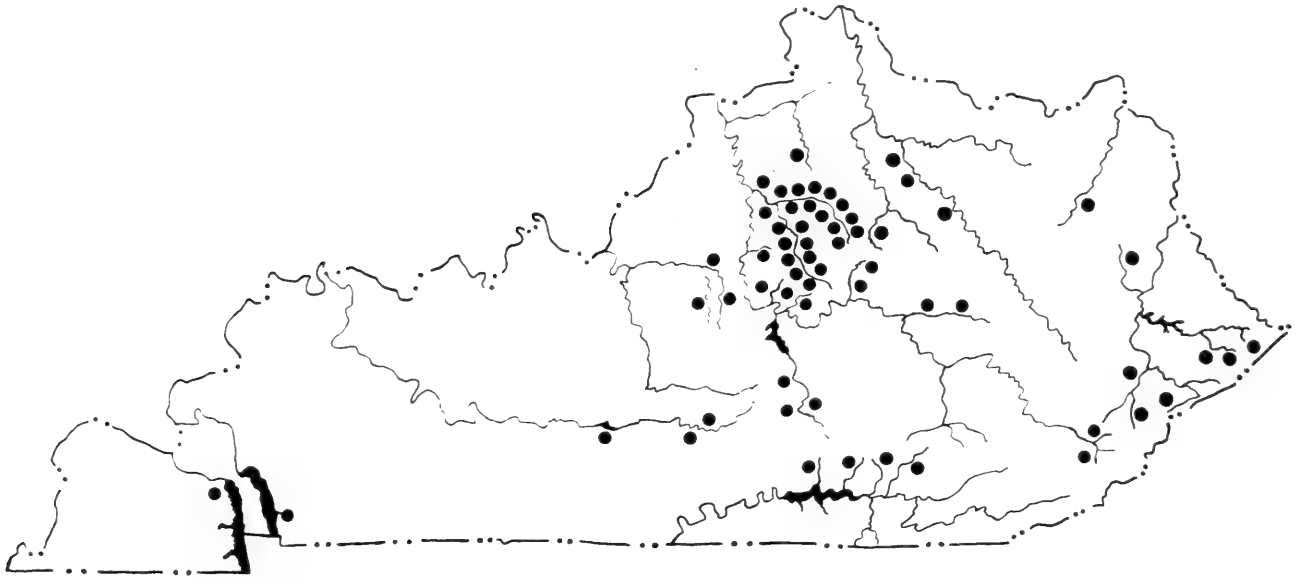

FIG. 1. Map of Kentucky indicating the locations of collections used in this study. The Little Sandy River site was negative and not included in the survey totals.

specimens and helpful comments, and especially Prof. J. M. Edney, University of Kentucky, my major professor, who provided much assistance. Recognition is made to Georgia College for a leave of absence stipend in 1971 and to the Faculty Research Fund of Georgia College for grants in 1971, 1972, and 1974. Special thanks to the survey teams of the Kentucky State Division of Fisheries which provided much cooperation.

METHODS

Most collections were made by me using a minnow seine, under the scientific collecting permit granted by the Kentucky Department of Fish and Wildlife Resources, Division of Fisheries. The Division of Fisheries provided 709 fishes taken by their stream survey teams in eastern and western Kentucky. My personal aircraft served as a means of rapid transportation from those areas. Collections were made from June through November 1971, August 1972, and May 1974, in 7 major river drainages throughout Kentucky (Fig. 1).

A representative sampling of fishes was attempted at each site. Every effort was made to bring live fish to the laboratory, including the adjustment of water temperature in the carrying tanks by use of ice. Fish were placed in several aerated 20-gallon (75-liter) aquaria to await postmortem examination. All fish that died after capture were immediately placed on ice and examined within 48 hours of reaching the laboratory.

Live fish were prepared for examination by pithing. The procedure was as follows: (1) host weight and species data were taken and a specimen code number formulated and recorded, (2) fish were examined for external parasites, and (3) the abdominal cavity was opened with dissecting scissors and the organs removed and examined under a dissection stereomicroscope capable of 30× magnification. The eyes, gills, liver and gall bladder, ovaries, kidneys, ureters, urinary bladder, and intestine were placed in separate petri dishes. In smaller fishes, those organs were teased apart under stereomicroscopic observation. Fish in excess of 100 g were dissected with fine scissors. The body wall was examined before carcass disposal. The worms from each host thus found were transferred into separate numbered holding vials with a small amount of saline.

Most Trematoda were fixed under slight coverslip pressure flattening with an 80 C solution of Bouin's fixative. All worms were subsequently transferred from the wet fixing slide to a vial of Bouin's fluid where

TABLE 1. LOCATION, HOST–PARASITE INTENSITY, AND INCIDENCE OF DIGENETIC TREMATODE PARASITES OF FISHES FROM MAJOR RIVER DRAINAGES IN KENTUCKY. NEGATIVE HOSTS ARE FISHES WITH NO PARASITES.

Location No. hosts–No. species	Host, mean weight, g	Trematode	Intensity, Incidence
BIG SANDY RIVER DRAINAGE			
Beaver Creek, Floyd County			
254–38	*Lepomis megalotis*, 41	*Pisciamphistoma stunkardi*	1.5, 2 of 6
Negative hosts (no.): *Dorosoma cepedianum* (2), *Esox americanus vermiculatus* (3), *Campostoma anomalum* (11), *Ericymba buccata* (24), *Notropis atherinoides* (6), *N. chrysocephalus* (16), *N. heterolepis* (2), *N. spilopterus* (2), *N. stramineus* (17), *Pimephales notatus* (9), *P. promelas* (3), *Rhinichthys atratulus* (6), *Semotilus atromaculatus* (16), *Carpiodes cyprinus* (2), *Catostomus commersoni* (4), *Hypentelium nigricans* (17), *Minytrema melanops* (5), *Moxostoma anisurum* (3), *M. erythrurum* (4), *Ictalurus melas* (1), *I. natalis* (2), *L. punctatus* (6), *Noturus miurus* (2), *Pylodictis olivaris* (2), *Labidesthes sicculus* (6), *Ambloplites rupestris* (15), *Lepomis gibbosus* (17), *L. macrochirus* (6), *L. microlophus* (2), *Micropterus dolomieui* (3), *M. punctulatus* (8), *M. salmoides* (4), *Pomoxis annularis* (2), *Etheostoma blennioides* (4), *E. caeruleum* (9), *E. flabellare* (2), *Percina caprodes* (5).			
LICKING RIVER DRAINAGE			
Licking River, Rowan and Menifee counties			
51–17	*Minytrema melanops*, 113	*Lissorchis* sp.	1, 7 of 11
	Micropterus punctulatus, 191	*Crepidostomum cornutum*	40, 5 of 5
Negative hosts (no.): *Anguilla rostrata* (2), *Campostoma anomalum* (1), *Cyprinus carpio* (2), *Notropis atherinoides* (10), *N. volucellus* (1), *Hypentelium nigricans* (3), *Ictiobus cyprinellus* (1), *Moxostoma anisurum* (2), *M. erythrurum* (7), *M. macrolepidotum* (1), *Ictalurus punctatus* (1), *Lepomis macrochirus* (2), *L. megalotis* (1), *Aplodinotus grunniens* (1).			
Stoner Creek, Bourbon County			
45–9	*Ambloplites rupestris*, 232	*Crepidostomum cornutum*	5, 1 of 1
	Lepomis macrochirus, 1	*Proterometra* sp.	4.5, 2 of 7
Negative hosts (no.): *Campostoma anomalum* (5), *Notropis ardens* (3), *N. boops* (1), *N. chrysocephalus* (12), *Labidesthes sicculus* (6), *Etheostoma blennioides* (6), *E. caeruleum* (4).			
Fleming Creek, Nicholas County			
27–10	*Noturus flavus*, 14	*Phyllodistomum lacustri*	6, 2 of 6
Negative hosts (no.): *Campostoma anomalum* (3), *Notropis rubellus* (2), *N. whipplei* (3), *Etheostoma blennioides* (3), *E. caeruleum* (4), *E. flabellare* (2), *E. zonale* (1), *Percina caprodes* (2), *P. phoxocephala* (1).			
Licking River, Nicholas County			
60–12	*Micropterus dolomieui*, 31	*Leuceruthrus micropteri*	2, 1 of 1
Negative hosts (no.): *Dorosoma cepedianum* (1), *Campostoma anomalum* (2), *Hybopsis aestivalis* (4), *Notropis rubellus* (1), *N. whipplei* (9), *Hypentelium nigricans* (1), *Noturus flavus* (5), *Etheostoma zonale* (14), *Percina caprodes* (7), *P. copelandi* (5), *P. evides* (1), *P. phoxocephala* (9).			
KENTUCKY RIVER DRAINAGE			
Line Fork, Letcher County			
62–15	*Notropis ardens*, 2.5	*Plagioporus* sp.	3, 3 of 8
	Semotilus atromaculatus, 34	*Plagioporus* sp.	2, 2 of 6
	Moxostoma macrolepidotum, 115	*Crepidostomum cornutum*[1]	2, 1 of 4
	Ambloplites rupestris, 44	*Crepidostomum cornutum*	4.5, 2 of 14
	Etheostoma flabellare, 6	*Phyllodistomum etheostomae*	2, 2 of 3
	Etheostoma spectabile, 1	*Phyllodistomum etheostomae*	2, 1 of 3
	Cottus carolinae, 11	*Proterometra* sp.	1, 1 of 5
Negative hosts (no.): *Nocomis micropogon* (1), *Notropis chrysocephalus* (2), *Carpiodes cyprinus* (4), *Ictalurus punctatus* (4), *Lepomis gibbosus* (2), *L. macrochirus* (2), *L. megalotis* (2), *Micropterus dolomieui* (2).			
Rockhouse Creek, Letcher County			
27–11	*Moxostoma macrolepidotum*, 102	*Phylodistomum lysteri*	2, 1 of 2
	Micropterus punctulatus, 199	*Crepidostomum cornutum*	2.5, 2 of 2

TABLE 1, Continued.

Location No. hosts–No. species	Host, mean weight, g	Trematode	Intensity, Incidence
	Ambloplites rupestris, 183	*Proterometra* sp.	4, 1 of 2
Negative hosts (no.): *Notropis chrysocephalus* (2), *Moxostoma erythrurum* (3), *Hypentelium nigricans* (2), *Noturus flavus* (4), *Pylodictis olivaris* (1), *Lepomis megalotis* (3), *Micropterus dolomieui* (2).			
Dix River, Lincoln County			
103–26	*Notropis ardens*, 2.5	*Plagioporus sinitsini*	4.5, 4 of 7
	Notropis chrysocephalus, 16	*Plagioporus sinitsini*	1, 1 of 14
	Ictalurus melas, 2.8	*Proterometra* sp.	6, 1 of 2
	Ambloplites rupestris, 159	*Proterometra* sp.	1, 1 of 3
	Lepomis cyanellus, 40	*Proterometra* sp.	4, 1 of 3
	Lepomis macrochirus, 70	*Proterometra* sp.	1, 1 of 4
	Lepomis megalotis, 61	*Proterometra* sp.	1, 2 of 6
	Micropterus salmoides, 220	*Proterometra* sp.	1, 1 of 5
Negative hosts (no.): *Dorosoma cepedianum* (1), *Campostoma anomalum* (6), *Cyprinus carpio* (2), *Notropis atherinoides* (2), *N. boops* (1), *Pimephales notatus* (1), *Semotilus atromaculatus* (14), *Hypentelium nigricans* (1), *Moxostoma erythrurum* (3), *Morone chrysops* (6), *Micropterus dolomieui* (1), *M. punctulatus* (5), *Etheostoma blennioides* (1), *E. caeruleum* (2), *E. flabellare* (6), *Percina caprodes* (5), *Aplodinotus grunniens* (1), *Cottus carolinae* (1).			
Red River, Powell County			
100–30	*Hiodon tergisus*, 193	*Paurorhynchus hiodontis*	17, 1 of 1
	Hypentelium nigricans, 40	*Phyllodistomum caudatum*	1.4, 5 of 7
	Hypentelium nigricans, 65	*Plagioporus sinitsini*	2, 2 of 7
	Moxostoma erythrurum, 71	*Clinostomum* (metacercariae)	4, 1 of 5
	Lepomis macrochirus, 62	*Proterometra* sp.	1, 1 of 1
	Lepomis megalotis, 11	*Leuceruthrus micropteri*	3, 1 of 5
	Percina caprodes, 9	*Crepidostomum isostomum*	1, 1 of 1
Negative hosts (no.): *Lepisosteus osseus* (2), *Anguilla rostrata* (2), *Dorosoma cepedianum* (5), *Campostoma anomalum* (5), *Cyprinus carpio* (2), *Nocomis effusus* (1), *Notropis boops* (5), *N. chrysocephalus* (1), *N. photogenis* (3), *Pimephales notatus* (3), *Moxostoma carinatum* (3), *M. duquesnei* (3), *M. macrolepidotum* (2), *Ictalurus punctatus* (1), *Ambloplites rupestris* (4), *Lepomis gibbosus* (1), *Micropterus punctulatus* (2), *Pomoxis annularis* (1), *Etheostoma blennioides* (6), *E. caeruleum* (2), *E. flabellare* (3), *E. variatum* (12), *E. zonale* (6), *Percina maculata* (2), *Aplodinotus grunniens* (3).			
Boone Creek, Fayette County			
142–17	*Notropis ardens*, 2.8	*Plagioporus sinitsini*	3, 3 of 17
	Notropis chrysocephalus, 15	*Allocreadium lobatum*	3, 6 of 26
	Notropis chrysocephalus, 12	*Plagioporus sinitsini*	2, 5 of 26
	Pimephales notatus, 12	*Plagioporus serotinus*	9, 3 of 18
	Semotilus atromaculatus, 7.5	*Phyllodistomum nocomis*	2, 1 of 10
	Catostomus commersoni, 148	*Lissorchis attenuatum*	3, 1 of 3
	Gambusia affinis, 2.5	*Plagioporus sinitsini*	24, 1 of 3
	Lepomis macrochirus, 23	*Leuceruthrus micropteri*	2, 2 of 4
	Lepomis macrochirus, 27	*Proterometra* sp.	5, 3 of 4
	Micropterus dolomieui, 1.3	*Leuceruthrus micropteri*	3, 1 of 2
	Micropterus dolomieui, 3.3	*Proterometra* sp.	1, 1 of 2
	Etheostoma blennioides, 2.1	*Podocotyle boleosomi*	3, 3 of 7
Negative hosts (no.): *Campostoma anomalum* (18), *Hypentelium nigricans* (3), *Lepomis cyanellus* (5), *Etheostoma caeruleum* (4), *E. flabellare* (11), *E. nigrum* (5), *E. spectabile* (3), *Cottus carolinae* (3).			
East Hickman Creek, Fayette County			
40–12	*Pimephales notatus*, 3.4	*Plagioporus sinitsini*	4, 1 of 3
	Lepomis cyanellus, 17	*Proterometra* sp.	1.5, 2 of 6
	Etheostoma blennioides, 3.1	*Phyllodistomum caudatum*	1, 1 of 2
	Etheostoma caeruleum, 2.0	*Proterometra* sp.	3, 1 of 3
	Etheostoma flabellare, 1.5	*Proterometra* sp.	2.5, 2 of 3

TABLE 1, Continued.

Location No. hosts–No. species	Host, mean weight, g	Trematode	Intensity, Incidence
Negative hosts (no.): *Notropis ardens* (5), *N. chrysocephalus* (6), *Semotilus atromaculatus* (2), *Lepomis macrochirus* (1), *L. megalotis* (5), *Etheostoma nigrum* (3), *Cottus carolinae* (1).			
Jessamine Creek, Jessamine County			
144–24	*Notropis chrysocephalus*, 34	*Allocreadium lobatum*	5, 3 of 10
	Notropis chrysocephalus, 27	*Plagioporus sinitsini*	6, 4 of 10
	Catostomus commersoni, 223	*Lissorchis attenuatum*	1, 1 of 4
	Ictalurus melas, 40	*Phyllodistomum caudatum*	11, 1 of 5
	Ambloplites rupestris, 89	*Crepidostomum cornutum*	3, 1 of 1
	Lepomis cyanellus, 28	*Proterometra* sp.	3.4, 7 of 10
	Lepomis gulosus, 18	*Proterometra* sp.	3, 1 of 1
	Lepomis macrochirus, 34	*Proterometra* sp.	5.1, 11 of 12
	Lepomis megalotis, 54	*Proterometra* sp.	1, 2 of 13
	Micropterus salmoides, 71	*Leuceruthrus micropteri*	2, 1 of 1
	Etheostoma blennioides, 0.5	*Podocotyle boleosomi*	1, 1 of 11
Negative hosts (no.): *Campostoma anomalum* (3), *Cyprinus carpio* (1), *Notropis ardens* (5), *N. photogenis* (7), *Pimephales notatus* (10), *Hypentelium nigricans* (6), *Moxostoma erythrurum* (4), *Noturus flavus* (1), *Micropterus punctulatus* (1), *Etheostoma caeruleum* (20), *E. flabellare* (11), *Percina caprodes* (1), *Cottus carolinae* (4).			
Grier Creek, Woodford County			
11–4	*Notropis chrysocephalus*, 53	*Allocreadium lobatum*	3, 3 of 5
	Notropis chrysocephalus, 52	*Plagioporus sinitsini*	3.5, 2 of 5
Negative hosts (no.): *Notropis ardens* (2), *Hypentelium nigricans* (3), *Catostomus commersoni* (1).			
South Elkhorn Creek, Fayette County			
110–9	*Notropis ardens*, 2.6	*Plagioporus* sp.	5, 3 of 46
	Notropis ardens, 2.5	*Plagioporus sinitsini*	5, 18 of 46
	Notropis chrysocephalus, 13	*Allocreadium lobatum*	2.4, 7 of 20
	Notropis chrysocephalus, 15	*Phyllodistomum nocomis*	3, 1 of 20
	Rhinichthys atratulus, 2	*Plagioporus sinitsini*	12, 1 of 2
	Semotilus atromaculatus, 17	*Allocreadium lobatum*	1, 1 of 14
	Lepomis macrochirus, 42	*Proterometra* sp.	20, 2 of 2
	Etheostoma blennioides, 3.3	*Podocotyle boleosomi*	1, 1 of 1
	Etheostoma flabellare, 2.2	*Proterometra* sp.	4.2, 5 of 8
	Cottus carolinae, 2.3	*Proterometra* sp.	1.3, 6 of 14
Negative host (no.): *Pimephales notatus* (5).			
North Elkhorn Creek, Fayette County			
722–34	*Notropis ardens*, 4.5	*Allocreadium lobatum*	1.4, 18 of 121
	Notropis ardens, 2.4	*Plagioporus* sp.	6, 29 of 121
	Notropis ardens, 2.0	*Plagioporus sinitsini*	4.4, 72 of 121
	Notropis chrysocephalus, 16	*Allocreadium lobatum*	2.3, 11 of 25
	Notropis chrysocephalus, 26	*Plagioporus sinitsini*	7, 2 of 25
	Notropis chrysocephalus, 37	*Bucephalopsis* sp.[2]	1, 1 of 25
	Pimephales notatus, 1.7	*Plagioporus sinitsini*	5, 3 of 67
	Pimephales notatus, 3.3	*Allocreadium lobatum*	1.3, 4 of 67
	Rhinichthys atratulus, 2.4	*Allocreadium lobatum*	2, 1 of 12
	Semotilus atromaculatus, 12	*Allocreadium lobatum*	3, 2 of 12
	Semotilus atromaculatus, 1	*Plagioporus* sp.	6, 1 of 12
	Ictalurus melas, 112	*Acetodextra amiuri*	4, 1 of 7
	Ambloplites rupestris, 147	*Crepidostomum cornutum*	21, 2 of 26
	Ambloplites rupestris, 87	*Phyllodistomum etheostomae*	4.3, 3 of 26
	Ambloplites rupestris, 27	*Proterometra macrostoma*	3, 3 of 26
	Lepomis cyanellus, 18	*Proterometra macrostoma*	6, 11 of 45
	Lepomis gulosus, 21	*Proterometra macrostoma*	7, 5 of 5
	Lepomis macrochirus, 14	*Proterometra macrostoma*	3.4, 26 of 52
	Lepomis megalotis, 50.4	*Proterometra macrostoma*	1, 1 of 28
	Micropterus dolomieui, 6	*Leuceruthrus micropteri*	6.5, 2 of 5
	Micropterus dolomieui, 6.9	*Proterometra macrostoma*	5.5, 2 of 5

TABLE 1, Continued.

Location No. hosts–No. species	Host, mean weight, g	Trematode	Intensity, Incidence
	Micropterus salmoides, 82	*Alloglossidium corti*	1.5, 2 of 13
	Micropterus salmoides, 139	*Crepidostomum cooperi*	21, 1 of 13
	Micropterus salmoides, 17	*Proterometra macrostoma*	10, 1 of 13
	Micropterus salmoides, 139	*Rhipidocotyle* sp.[2]	1, 1 of 13
	Etheostoma sp., 1	*Proterometra* sp.	1, 1 of 4
	Etheostoma caeruleum, 1	*Podocotyle boleosomi*	4.9, 7 of 28
	Etheostoma caeruleum, 1.7	*Proterometra* sp.	1.8, 6 of 28
	Etheostoma flabellare, 0.9	*Phyllodistomum etheostomae*	1, 4 of 50
	Etheostoma flabellare, 1.1	*Podocotyle boleosomi*	2.2, 10 of 50
	Etheostoma flabellare, 0.9	*Proterometra* sp.	2.4, 21 of 50
	Etheostoma nigrum, 1	*Proterometra* sp.	1, 1 of 6
	Etheostoma spectabile, 1.4	*Allocreadium lobatum*	1, 2 of 19
	Etheostoma spectabile, 1.1	*Podocotyle boleosomi*	3, 2 of 19
	Etheostoma spectabile, 1.3	*Proterometra* sp.	1.6, 7 of 19
	Cottus carolinae, 4.1	*Proterometra macrostoma*	2, 16 of 43
	Cottus carolinae, 1.5	*Proterometra* sp.	2, 2 of 43
Negative hosts (no.): *Salmo gairdneri* (3), *Campostoma anomalum* (41), *Notropis boops* (1), *N. rubellus* (4), *N. photogenis* (4), *Pimephales promelas* (2), *Catostomus commersoni* (19), *Hypentelium nigricans* (13), *Moxostoma anisurum* (1), *Ictalurus natalis* (4), *Fundulus notatus* (2), *Gambusia affinis* (21), *Labidesthes sicculus* (18), *Pomoxis annularis* (11), *Micropterus punctulatus* (10).			
North Elkhorn Creek, Scott County			
335–30	*Notropis ardens*, 2.5	*Allocreadium lobatum*	2, 1 of 39
	Notropis ardens, 1.2	*Plagioporus* sp.	3.1, 9 of 39
	Notropis boops, 2	*Plagioporus sinitsini*	10, 1 of 2
	Notropis chrysocephalus, 17	*Allocreadium lobatum*	2, 1 of 4
	Pimephales notatus, 1	*Plagioporus cooperi*	11, 1 of 27
	Pimephales notatus, 1.1	*Plagioporus sinitsini*	13, 2 of 27
	Pimephales promelas, 1.8	*Plagioporus cooperi*	6, 1 of 12
	Rhinichthys atratulus, 1.0	*Allocreadium lobatum*	2, 1 of 3
	Semotilus atromaculatus, 2.1	*Plagioporus* sp.	1, 1 of 3
	Moxostoma anisurum, 48	*Plagioporus sinitsini*	2, 1 of 1
	Ictalurus melas, 23.4	*Acetodextra amiuri*	4, 1 of 28
	Ictalurus natalis, 0.8	*Acetodextra amiuri*	7, 1 of 1
	Lepomis cyanellus, 29	*Crepidostomum cooperi*	10, 2 of 60
	Lepomis cyanellus, 20.5	*Proterometra* sp.	3, 21 of 60
	Lepomis cyanellus, 25	*Phyllodistomum nocomis*[1]	1, 1 of 60
	Lepomis gulosus, 72.5	*Proterometra* sp.	1, 1 of 1
	Lepomis gulosus, 72.5	*Allocreadium lobatum*[1]	1, 1 of 1
	Lepomis macrochirus, 25	*Proterometra* sp.	8.8, 17 of 39
	Lepomis megalotis, 27	*Proterometra* sp.	3, 5 of 17
	Micropterus salmoides, 4.2	*Leuceruthrus micropteri*	1.5, 2 of 24
	Cottus carolinae, 7.2	*Proterometra* sp.	8, 1 of 4
Negative hosts (no.): *Campostoma anomalum* (2), *Notemigonus crysoleucas* (1), *Notropis atherinoides* (5), *N. hudsonius* (5), *N. whipplei* (5), *Catostomus commersoni* (3), *Moxostoma erythrurum* (2), *Fundulus notatus* (4), *Gambusia affinis* (2), *Labidesthes sicculus* (9), *Micropterus punctulatus* (2), *Pomoxis annularis* (3), *Etheostoma blennioides* (1), *E. flabellare* (6), *E. nigrum* (2), *E. spectabile* (18).			
Elkhorn River, Franklin County			
96–17	*Campostoma anomalum*, 2	*Plagioporus sinitsini*	2, 1 of 9
	Notropis ardens, 1.9	*Plagioporus sinitsini*	3, 4 of 13
	Notropis chrysocephalus, 16	*Allocreadium lobatum*	2, 2 of 10
	Notropis whipplei, 6.6	*Allocreadium lobatum*	1, 1 of 11
	Notropis whipplei, 6.6	*Plagioporus sinitsini*	11, 1 of 11
	Ambloplites rupestris, 6.1	*Proterometra* sp.	1, 1 of 2
	Lepomis cyanellus, 12	*Proterometra* sp.	3, 2 of 4
	Lepomis gulosus, 88	*Proterometra* sp.	2, 1 of 1

TABLE 1, Continued.

Location No. hosts–No. species	Host, mean weight, g	Trematode	Intensity, Incidence
	Lepomis macrochirus, 30	*Proterometra* sp.	5.4, 14 of 17
	Micropterus salmoides, 20	*Leuceruthrus micropteri*	4, 6 of 16
Negative hosts (no.): *Carassius auratus* (5), *Cyprinus carpio* (1), *Notropis boops* (1), *N. spilopterus* (8), *Pimephales notatus* (2), *Catostomus commersoni* (2), *Ictalurus natalis* (9), *Micropterus dolomieui* (2).			
Eagle Creek, Scott County			
105–17	*Notropis chrysocephalus*, 22	*Allocreadium lobatum*	1, 2 of 12
	Lepomis cyanellus, 29	*Proterometra* sp.	2.7, 3 of 12
	Lepomis megalotis, 19	*Proterometra* sp.	1, 2 of 6
Negative hosts (no.): *Campostoma anomalum* (4), *Notropis ardens* (8), *Pimephales notatus* (6), *Semotilus atromaculatus* (11), *Catostomus commersoni* (2), *Hypentelium nigricans* (2), *Fundulus notatus* (1), *Ictalurus melas* (5), *Labidesthes sicculus* (1), *Micropterus punctulatus* (3), *M. salmoides* (1), *Etheostoma flabellare* (16), *Percina caprodes* (4), *P. maculata* (5).			
CUMBERLAND RIVER DRAINAGE			
Horselick Creek, Jackson County			
49–17	*Notropis chrysocephalus*, 21	*Allocreadium lobatum*	3, 1 of 4
	Notropis rubellus, 2.9	*Plagioporus sinitsini*	6, 1 of 4
	Micropterus dolomieui, 6.5	*Leuceruthrus micropteri*	1, 1 of 2
	Etheostoma caeruleum, 3.4	*Proterometra* sp.	1, 2 of 7
Negative hosts (no.): *Campostoma anomalum* (1), *Notropis atherinoides* (1), *N. galacturus* (5), *Pimephales notatus* (4), *Ambloplites rupestris* (2), *Lepomis macrochirus* (2), *L. microlophus* (2), *Etheostoma blennioides* (7), *E. camurum* (4), *E. flabellare* (2), *E. stigmaeum* (1), *Percina caprodes* (1), *P. maculata* (1), *Cottus carolinae* (1).			
Rockcastle River, Rockcastle and Laurel counties			
38–11	*Etheostoma blennioides*, 9.3	*Crepidostomum isostomum*	1, 1 of 11
	Etheostoma blennioides, 7.1	*Podocotyle boleosomi*	4.3, 3 of 11
Negative hosts (no.): *Campostoma anomalum* (3), *Nocomis micropogon* (1), *Notropis chrysocephalus* (12), *Pimephales notatus* (2), *Semotilus atromaculatus* (1), *Hypentelium nigricans* (1), *Ambloplites rupestris* (2), *Lepomis megalotis* (2), *Etheostoma camurum* (1), *Percina caprodes* (2).			
Buck Creek, Pulaski County			
55–14	*Notropis chrysocephalus*, 28	*Allocreadium lobatum*	1, 1 of 10
	Notropis chrysocephalus, 19	*Plagioporus sinitsini*	7, 4 of 10
Negative hosts (no.): *Campostoma anomalum* (1), *Notropis boops* (1), *Pimephales notatus* (4), *Hypentelium nigricans* (1), *Noturus flavus* (1), *Fundulus catenatus* (4), *Ambloplites rupestris* (2), *Lepomis cyanellus* (5), *L. macrochirus* (4), *L. megalotis* (4), *Etheostoma caeruleum* (12), *E. flabellare* (4), *E. virgatum* (2).			
Pitman Creek, Pulaski County			
49–16	*Ambloplites rupestris*, 13	*Proterometra* sp.	1, 1 of 4
	Ambloplites rupestris, 13	*Rhipidocotyle* sp.[2]	11, 1 of 4
	Etheostoma caeruleum, 2.1	*Phyllodistomum etheostomae*	1, 1 of 11
Negative hosts (no.): *Campostoma anomalum* (1), *Notropis ardens* (5), *N. chrysocephalus* (1), *N. spilopterus* (5), *Pimephales notatus* (3), *Hypentelium nigricans* (1), *Fundulus catenatus* (1), *Lepomis macrochirus* (1), *L. megalotis* (1), *Micropterus dolomieui* (1), *Etheostoma blennioides* (1), *E. flabellare* (1), *E. obeyense* (8), *E. rufilineatum* (4).			
Fishing Creek, Pulaski County			
31–10	*Etheostoma blennioides*, 2	*Pisciamphistoma stunkardi*	1, 1 of 1
Negative hosts (no.): *Campostoma anomalum* (1), *Fundulus catenatus* (2), *Lepomis macrochirus* (4), *L. megalotis* (3), *Micropterus punctulatus* (2), *Etheostoma caeruleum* (1), *E. flabellare* (1), *E. rufilineatum* (12), *Percina caprodes* (2).			
Lake Barkley, Trigg County			
41–11	*Ictiobus bubalus*, 1,341	*Rhipidocotyle* sp.[2]	6, 2 of 7
	Lepomis macrochirus, 92	*Crepidostomum cornutum*	10, 1 of 8
Negative hosts (no.): *Cyprinus carpio* (3), *Minytrema melanops* (2), *Ictalurus natalis* (2), *I. nebulosus* (1), *I. punctatus* (1), *Lepomis megalotis* (5), *Micropterus salmoides* (3), *Pomoxis annularis* (4), *Aplodinotus grunniens* (5).			

TABLE 1, Continued.

Location No. hosts–No. species	Host, mean weight, g	Trematode	Intensity, Incidence
SALT RIVER DRAINAGE			
Salt River, Anderson County			
48–11	*Lepomis cyanellus*, 8.3	*Proterometra* sp.	1.3, 3 of 7
Negative hosts (no.): *Campostoma anomalum* (4), *Notropis ardens* (4), *N. boops* (1), *N. whipplei* (2), *Pimephales notatus* (2), *Fundulus notatus* (1), *Ambloplites rupestris* (3), *Etheostoma blennioides* (8), *E. flabellare* (15), *Cottus carolinae* (1).			
Chaplin River, Boyle County			
63–9	*Notropis ardens*, 1.5	*Plagioporus sinitsini*	2, 3 of 9
	Pimephales notatus, 2.8	*Plagioporus sinitsini*	2.3, 3 of 10
	Lepomis cyanellus, 3.2	*Proterometra* sp.	1.6, 5 of 5
	Lepomis macrochirus, 2.8	*Proterometra* sp.	1.5, 2 of 4
Negative hosts (no.): *Campostoma anomalum* (2), *Notropis boops* (12), *N. chrysocephalus* (14), *Labidesthes sicculus* (2), *Lepomis macrochirus* (5).			
Chaplin River, Mercer County			
32–12	*Catostomus commersoni*, 91	*Rhipidocotyle* sp.[2]	8, 1 of 3
	Moxostoma erythrurum, 284	*Rhipidocotyle* sp.[2]	1, 1 of 1
	Ictalurus natalis, 8	*Phyllodistomum staffordi*	6, 1 of 1
	Lepomis macrochirus, 1.6	*Proterometra* sp.	1, 2 of 4
	Lepomis megalotis, 48	*Crepidostomum cornutum*	9, 1 of 4
	Lepomis megalotis, 38	*Rhipidocotyle septpapillata*	12, 3 of 4
	Etheostoma flabellare, 1.6	*Podocotyle boleosomi*	1, 2 of 8
	Etheostoma flabellare, 1.4	*Phyllodistomum etheostomae*	2, 3 of 8
Negative hosts (no.): *Notropis atherinoides* (1), *N. chrysocephalus* (4), *Pimephales notatus* (2), *Semotilus atromaculatus* (1), *Micropterus punctulatus* (2), *Etheostoma caeruleum* (1).			
GREEN RIVER DRAINAGE			
Green River, Casey County			
148–26	*Minytrema melanops*, 129	*Lissorchis simeri*	9, 1 of 1
	Noturus gyrinus, 5.5	*Proterometra* sp.	4, 1 of 1
	Lepomis cyanellus, 2.1	*Proterometra* sp.	2, 1 of 2
	Lepomis macrochirus, 7.2	*Proterometra* sp.	2, 2 of 2
	Lepomis megalotis, 18	*Proterometra* sp.	2, 3 of 8
	Lepomis megalotis, 21	*Rhipidocotyle* sp.[2]	10, 4 of 8
	Micropterus punctulatus, 24.7	*Proterometra* sp.	2, 1 of 3
	Pomoxis annularis, 92	*Proterometra* sp.	3, 1 of 1
	Etheostoma blennioides, 4.4	*Crepidostomum isostomum*	2, 2 of 24
	Etheostoma blennioides, 3.9	*Podocotyle boleosomi*	2.5, 2 of 24
Negative hosts (no.): *Dorosoma cepedianum* (2), *Campostoma anomalum* (8), *Cyprinus carpio* (3), *Notropis ardens* (4), *N. chrysocephalus* (6), *N. spilopterus* (7), *N. whipplei* (2), *Pimephales notatus* (1), *Moxostoma erythrurum* (1), *Fundulus catenatus* (9), *Labidesthes sicculus* (1), *Ambloplites rupestris* (3), *Micropterus salmoides* (2), *Etheostoma bellum* (30), *E. caeruleum* (9), *E. flabellare* (8), *E. zonale* (8), *Percina caprodes* (2).			
Green River Reservoir, Taylor County			
18–7	*Minytrema melanops*, 232	*Phyllodistomum* sp.[2]	21, 2 of 5
Negative hosts (no.): *Cyprinus carpio* (1), *Moxostoma anisurum* (3), *Lepomis cyanellus* (1), *L. megalotis* (2), *Micropterus salmoides* (5), *Pomoxis annularis* (1).			
TENNESSEE RIVER DRAINAGE			
Kentucky Lake, Marshall County			
53–17	*Ictiobus bubalus*, 74	*Rhipidocotyle* sp.[2]	5, 1 of 1
	Ictalurus punctatus, 1,039	*Phyllodistomum lacustri*	2.8, 4 of 7
Negative hosts (no.): *Alosa chrysochloris* (3), *Hiodon alosoides* (1), *Cyprinus carpio* (3), *Hybopsis storeriana* (5), *Minytrema melanops* (4), *Morone mississippiensis* (2), *Lepomis macrochirus* (2), *L. megalotis* (4), *L. microlophus* (1), *Micropterus punctulatus* (2), *M. salmoides* (7), *Pomoxis annularis* (2), *Percina caprodes* (1), *Stizostedion canadense* (2), *Aplodinotus grunniens* (6).			

[1] Probably accidental.
[2] Immature specimens.

they remained overnight, then decanted and refilled with 70 percent ethyl alcohol and 0.5 percent lithium carbonate to remove excess picric acid, finally to a solution of 70 percent ethyl alochol and 5 percent glycerine for storage.

Adult trematodes were stained regressively with Harris's haematoxylin. Subsequent destaining and neutralization, dehydration, clearing, and mounting steps were accomplished by standard technique.

All measurements are reported in millimeters. The sucker size ratio compares the size of the oral sucker with that of the acetabulum (i.e., 2–1, 0.53–1), respectively. Sucker sizes were determined by averaging length and width, therefore comparing the general sizes of those structures (Manter 1969).

The term "mean intensity" refers to the average number of adult trematode specimens per infested host fish. The term "incidence" (i.e., 5 of 6) refers to the number of infested host fishes as compared to the total number examined at each location. Fish taxa are listed in the order and nomenclature of Bailey et al. (1970). Trematode taxa are referenced in Yamaguti (1971) and follow the order of Hoffman (1967).

RESULTS

Taxonomic information and records of collection are presented in alphabetical order of trematode family, genus, and species. Total mean intensity and incidence data (i.e., 2.6, 50 of 110) from appropriate locations are presented for each parasite (Table 1).

ALLOCREADIIDAE

Allocreadium lobatum.—Specimens were recovered from *Notropis chrysocephalus* (2.8, 37 of 126). New host records occur from *N. whipplei* (1, 1 of 11), *Rhinichthys atratulus* (2, 2 of 15), and 1 probably accidental occurrence in *Lepomis gibbosus.* Many immature (nongravid) specimens of *A. lobatum* were collected from *N. chrysocephalus.* Those specimens demonstrated testicular lobation even when sparse testicular primordia were present. *A. lobatum* was recovered from host fish in the Kentucky and Cumberland river basins. Also, specimens possessing an entire or slightly indented ovary were recovered from *N. ardens* (1.4, 19 of 186), *Pimephales notatus* (1.3, 4 of 99), *Semotilus atromaculatus* (2.3, 3 of 26), and *Etheostoma spectabile* (1, 2 of 37) from North and South Elkhorn creeks. Host induced variation may explain the ovarian structure.

Crepidostomum cooperi.—One anatomical variation present in smaller *C. cooperi* (0.58–0.65 mm long) is a posterodorsal depression. As worm length increased in fixed specimens, the depression gradually disappeared. This form occurred only at 1 site on North Elkhorn Creek, Scott County, near Stamping Ground, 20 specimens recovered from 2 *Lepomis cyanellus* hosts. Specimens were recovered from the intestine and primarily the intestinal caeca of *L. cyanellus* (10, 2 of 105) and *Micropterus salmoides* (21, 1 of 27) from North Elkhorn Creek.

Crepidostomum cornutum.—Specimens were recovered from the intestine of *Ambloplites rupestris* (10, 6 of 42), *Lepomis macrochirus* (10, 1 of 76), *L. megalotis* (9, 1 of 56), and *Micropterus punctulatus* (30, 7 of 28). The report from *L. megalotis* constitutes a new host record. *C. cornutum* was recovered from the Licking, Kentucky, Salt, and Tennessee river drainages.

Crepidostomum isostomum.—Specimens were discovered parasitizing the intestine of *Etheostoma blennioides* (1, 3 of 41) from the Red River in the Kentucky River drainage and *Percina caprodes* (1, 1 of 5) from the Cumberland River basin. *E. blennioides* is a new host record.

AZYGIIDAE

Leuceruthrus micropteri.—Specimens were recovered from the cardiac stomach of *Lepomis macrochirus* (2, 2 of 127), *L. megalotis* (immature, 3, 1 of 63), *Micropterus dolomieui* (3.8, 5 of 12), and *M. salmoides* (3.2, 9 of 54). Fourteen *M. punctulatus* at appropriate locations were negative. The reports from *L. macrochirus* and

L. megalotis constitute new host records. *L. micropteri* was recovered from the Kentucky, Licking, and Cumberland river basins.

Proterometra sp.—Generally adult morphological characteristics of *Proterometra* sp. do not provide sufficient means for identification. Anderson and Anderson (1967) and Yamaguti (1971) suggested that morphologically distinct types of cercariae provide the best criteria for identification as differences at any phase of development must be significant.

Proterometra macrostoma.—This form probably is the only large *Proterometra* in North Elkhorn Creek, Fayette County, as snail hosts that produce these cercariae have been collected by J. M. Edney (pers. comm.), parasitology students since 1948, and me yearly since 1971 (identity confirmed by M. G. Anderson, pers. comm.). Many other collecting sites yielded *P. macrostoma*-like adults, as distinguished by ovoid testes, vitellaria extent, sucker size ratio, and size (about 1.4 mm after fixation). Including data from appropriate sites, where *P. macrostoma* and *P. macrostoma*-like specimens were collected, the mean intensity and incidence figures in Table 1 could indicate a relative fitness of the host–parasite relationship.

P. macrostoma and *P. macrostoma*-like specimens demonstrated a mean intensity of 5.1 and an incidence of 53 percent (83 of 157) in *Lepomis macrochirus*, *L. cyanellus* demonstrated a mean intensity of 3 and incidence of 38 percent (60 of 157), but *L. megalotis* demonstrated a mean intensity of 1.9 and an incidence of 15 percent (15 of 101). Those figures suggest a lower host–parasite fitness for *L. megalotis*. Other comparative figures, less significant by reason of smaller numbers of hosts examined, are 2.8 and 21 percent (11 of 52) for *Ambloplites rupestris*, 2.1 and 32 percent (24 of 76) for *Cottus carolinae*, and 4.2 and 6 percent (6 of 105) in *Micropterus* (4, 3 of 17 for *M. dolomieui*, 2, 1 of 27 for *M. punctulatus*, and 5.5, 2 of 63 for *M. salmoides*). *Proterometra* sp. was also recovered from *Ictalurus melas* (6, 1 of 47), *Noturus gyrinus* (1, 1 of 1) *L. gulosus* (5.3, 8 of 8), and *Pomoxis annularis* (3, 1 of 16). The records for *I. melas*, *N. gyrinus*, *L. gulosus*, *M. dolomieui*, *M. punctulatus*, *M. salmoides*, and *C. carolinae* designate new hosts for *P. macrostoma.* Host locations were the Kentucky, Licking, Cumberland, Salt, and Green rivers, thus placing it as the most ubiquitous adult digenetic trematode genus in Kentucky.

The *Proterometra* sp. from *Etheostoma caeruleum* (1.8, 9 of 38), *E. flabellare* (2.7, 28 of 63), *E. spectabile* (1.6, 7 of 19), and *Cottus carolinae* (2, 2 of 59) is smaller (0.8 mm after fixation) than the *P. macrostoma*-like specimens and is thought to be a new adult and cercarial form (pending publication).

BUCEPHALIDAE

Paurorhynchus hiodontis.—Specimens were found in the body cavity of 1 *Hiodon tergisus* (17, 1 of 1) from the Red River, Kentucky River drainage.

Rhipidocotyle septpapillata.—This form was found in the intestine of *Lepomis megalotis* (12, 3 of 4) from the Salt River drainage, a new host record. This trematode was differentiated on the basis of the pentagonal cap and excretory vesicle flexure just posterior to the rhynchus. *Rhipidocotyle* sp. was recorded from the following hosts which harbored sterile immature forms: *Catostomus commersoni* (8, 1 of 3), *Ictiobus bubalis* (6, 3 of 8), *Moxostoma erythrurum* (1, 1 of 1), *Ambloplites rupestris* (11, 1 of 7), *Lepomis megalotis* (12, 3 of 10), and *Micropterus salmoides* (1, 1 of 26); it was chosen as generic identity for the presumed immature forms by reason of similarity of many nonpapillate forms recovered simultaneously with mature *P. septpapillata* from a single host *L. megalotis*. Because of the uncertain identity of many specimens, no new host records are claimed. *Rhipidocotyle* sp. was recovered from the Cumberland, Salt, Green, and Tennessee river drainages.

Bucephalopsis sp.—One gravid specimen was recovered from *Notropis chrysocephalus* (1, 1 of 25). The specimen is a progenetic metacercaria similar to that described by Hoffman (1953).

Some discussion of bucephalid morphology is required at this juncture. Woodhead (1930) and Van Cleave and Mueller (1934) reported morphological changes due to host induced variation and age of trematode specimens. Bucephalid genera parasitizing fishes are differentiated according to rhynchus structure as follows: rhynchus without appendages, *Bucephalopsis*; rhynchus weakly developed, *Paurorhynchus*; rhynchus with tentacular appendages, *Bucephalus*; and rhynchus with pentagonal cap, *Rhipidocotyle*.

Metacercariae, immature, and young gravid bucephalids generally do not exhibit appendages and are therefore difficult to identify. The metacercariae occur in fishes susceptible to predation by larger fishes such as *Micropterus salmoides* which serve as definitive hosts.

CRYPTOGONIMIDAE

Acetodextra amiuri.—Specimens were obtained from the gas bladder of *Ictalurus melas* (4, 1 of 28) and *I. natalis* (7, 1 of 1) from 2 locations in North Elkhorn Creek, Kentucky river basin. Large numbers of eggs frequently obscure the midposterior organs of gravid *Acetodextra*.

GORGODERIDAE

Phyllodistomum caudatum.—Specimens were recovered from the urinary bladder of *Hypentelium nigricans* (1.4, 5 of 26), *Ictalurus melas* (7.5, 2 of 12), and *Etheostoma blennioides* (1, 1 of 8) from the Kentucky River drainage. New host records occur for *H. nigricans* and *E. blennioides*.

Phyllodistomum etheostomae.—The Kentucky specimens demonstrate consistent but slight anatomical differences from those described originally in that the testes, and especially the ovary, exhibit a greater extent of lobation, and the sucker ratio is somewhat larger (1.0–0.68 for specimens from Kentucky and 1.0–0.85 for specimens from Wisconsin). Both forms have 2 pairs of folds on the discoidal hindbody. This form occurred in *Ambloplites rupestris* (4.3, 3 of 44), *Etheostoma caeruleum* (1, 1 of 39), *E. flabellare* (6, 9 of 61), and *E. spectabile* (2, 1 of 22) from the Kentucky and Cumberland river drainages. The reports for *A. rupestris*, *E. caeruleum*, and *E. spectabile* constitute new host records.

Phyllodistomum lacustri.—Specimens were found parasitizing the urinary bladders of *Ictalurus punctatus* (2.8, 4 of 7) and *Noturus flavus* (6, 2 of 6) from the Licking River and Cumberland River (Lake Barkley) drainages, respectively. The occurrence in *N. flavus* is a new host record.

Phyllodistomum lysteri.—Specimens were recovered from *Moxostoma macrolepidotum* (1, 1 of 2) from Rockhouse Creek of the Kentucky River drainage, a new host record.

Phyllodistomum nocomis.—Adults occurred in the urinary bladder of *Notropis chrysocephalus* (3, 1 of 46) and *Semotilus atromaculatus* (2, 1 of 10), new host records, and a broken specimen (from ingestion of former host?) in the intestine of *Lepomis cyanellus* (1, 1 of 60). All specimens were from the Kentucky River drainage.

Phyllodistomum staffordi.—Specimens were taken from the urinary bladder of an *Ictalurus natalis* (1, 1 of 1) from the Salt River.

LISSORCHIDAE

Lissorchis (Triganodistomum) attenuatum.—Individuals were found in the intestine of *Catostomus commersoni* (3, 1 of 3) from Boone Creek, Kentucky River drainage.

Lissorchis (Triganodistomum) simeri.—Specimens were recovered from the intestine of *Minytrema melanops* (9, 1 of 1) from the Green River, a new host record.

The *Lissorchis* sp. from *M. melanops* (1, 7 of 11) from the Licking River is thought to be a new form.

MACRODEROIDAE

Alloglossidium corti.—Adults were recovered from the intestine of *Micropterus salmoides* from North Elkhorn Creek, Kentucky River drainage, a new host record.

OPECOELIDAE

Plagioporus cooperi.—Specimens were recovered from the intestines of *Pimephales notatus* (11, 1 of 27) and *P. promelas* (6, 1 of 12) from a single location on North Elkhorn Creek in Scott County. Both hosts are new records. One significant morphological difference occurred in *P. cooperi* specimens in this study, that of 3 to 5 ovarian lobes. A second difference was a smaller egg size of 0.067 × 0.044 mm for the Kentucky specimens as compared to 0.086 × 0.047 in the specimens of the original description. There was some variation in anatomy in the 11 specimens from *P. notatus*; they had fewer posttesticular vitellaria, and 8 of the 11 had caeca extending to the posterior margin of the posterior testis.

Plagioporus serotinus.—Adults were recovered in 1971 from the gall bladder of *Pimephales notatus* (9, 3 of 18) from Boone Creek, Fayette County. There were curious cuticular ridges in many of the specimens. However, Dobrovolny (1939a) noted cuticular striations similar to those ridges. J. H. Fischthal (pers. comm.) stated that "the projections are tegumental extensions of unknown nature." in reference to those specimens.

Plagioporus sinitsini.—Adults were taken from the gall bladders of host fishes as follows: *Campostoma anomalum* (2, 1 of 76), *Notropis ardens* (4.3, 104 of 259), *N. boops* (10, 1 of 23), *N. chrysocephalus* (4.8, 18 of 103), *N. rubellus* (6, 2 of 7), *N. whipplei* (11, 1 of 16), *Pimephales notatus* (5.8, 6 of 124), *Rhinichthys atratulus* (12, 1 of 17), and *Gambusia affinis* (24, 1 of 26) from the Kentucky, Cumberland, and Salt river drainages, and all constitute new records. Those specimens designated *Plagioporus* sp. from *N. ardens* (2.8, 4 of 21) of the Kentucky River drainage are thought to be a new form.

Podocotyle boleosomi.—Specimens were recovered from *Etheostoma blennioides* (2.9, 10 of 54), *E. caeruleum* (4.9, 7 of 25), *E. flabellare* (4.9, 7 of 62), and *E. spectabile* (3, 2 of 22) from the Kentucky, Salt, and Green river basins.

Pearse (1924) described *Allocreadium boleosomi.* Study of the type specimen USNM #7622 shows that the esophagus of *P. boleosomi* has 1 loop and therefore it could appear to be longer than the pharynx in a slightly coverslip pressed specimen. Peters (1957) synonymized *P.* (*Allocreadium*) *boleosomi* with *Podocotyle* (*Plagioporus*) *lepomis* (Dobrovolny 1939b) but Pritchard (1966) reinstated *P. lepomis* and *P. boleosomi* as distinguished by ova size, 0.080–0.114 by 0.051–0.077 vs. 0.064–0.085 by 0.035–0.045 mm, respectively. Pritchard (1966) excluded *P. boleosomi* from the Opecoelidae because it was spined. However, Yamaguti (1971) retained the designation *Podocotyle boleosomi.* The Kentucky specimens are aspinous. Three specimens of *Podocotyle boleosomi* have been deposited in the Manter Collection, University of Nebraska State Museum No. 20311.

Importantly, this survey and Pearse (1924) recorded apparent host specificity of *P. boleosomi* from percids *Etheostoma* spp. and *Percina* spp. Dobrovolny (1939b) attempted experimental infestation of *P. lepomis* with cyprinid, centrarchid, and percid hosts, succeeding only with *Lepomis* spp. The survey records of Dobrovolny (1939a, 1939b) also indicated host specificity for *Lepomis* spp.

PARAMPHISTOMATIDAE

Pisciamphistoma stunkardi.—Specimens were obtained from *Lepomis megalotis* (1.5, 2 of 9) from the Big Sandy River drainage. The host constituted the only adult digenetic trematode found in the drainage (254 fishes sampled). Mine acid in this drainage probably has reduced the molluscan (host) populations drastically. One nongravid *P. stunkardi* was recovered from *Etheostoma blennioides* (1, 1 of 15) from

Fishing Creek, Cumberland River drainage. Both are new host records.

DISCUSSION

The apparent decrease in certain stream fauna and the relative scarcity of parasite records from Kentucky provided impetus for this study to describe the adult digenetic trematode fauna of Kentucky fishes. But the aquatic biologist may be faced with a race against time when attempting to describe the flora and fauna of many freshwater streams in the world. A vivid experience brings this situation into focus. While travelling with the Kentucky Department of Fisheries survey team in August 1971, a survey was attempted on a small mountain creek in Pike County. The creek was adjacent to a roadside park, and at first glance it appeared to be a clear, free-flowing stream. Subsequent examination of 40 m of stream revealed iron pyrite sedimentation on the bottom, a pH of 3.8, and not a single living fish or other aquatic organism. Furthermore, of 254 fishes collected from the Big Sandy River drainage in eastern Kentucky, an area of heavy strip mining, only 2 *Lepomis megalotis* harbored adult digenetic trematodes.

Yamaguti (1971) listed approximately 5,000 species of digenetic trematodes. Of those, 1,500 were recorded from fishes, 1,000 from marine species and 500 from freshwater species. Manter (1969) suggested that "the total number from fishes must be very much greater, perhaps 10-fold."

Many large surveys have been undertaken during the last 40 years to expand our knowledge of fish parasites. Van Cleave and Mueller (1932, 1934) conducted a very thorough survey at Lake Oneida, New York, in which 1,227 fishes of 34 species were examined. Fischthal (1947) collected 2,059 fishes of 44 species and listed 30 species of adult Digenea. Bangham and Adams (1954) conducted the largest freshwater survey in British Columbia, collecting 5,456 fishes of 36 species that yielded 12 species of Digenea.

Those studies may be compared to this survey of 3,059 fishes of 17 families and 91 species from which 23 species of adult digenetic trematodes comprising 8 families have been identified. The collection records confirm a generalization (Manter 1969) about host specificity of freshwater Digenea which suggests that few species are known to consistently infest fishes of different families.

The most prevalent parasites wer *Proterometra* spp. and *Plagioporus* spp. Their prevalence is due to the widespread occurrence of *Goniobasis* and *Pleurocera* snails in upland streams of Kentucky.

The well-known rule for distribution of adult Digenea is that they parallel the distribution of their molluscan hosts. Yamaguti (1971) and Hoffman (1967) listed the following molluscan hosts for the species recovered in addition to *Proterometra* spp. and *Plagioporus* spp.: *Allocreadium lobatum* in *Pisidium* clams, *Crepidostomum cornutum* in *Musculium* and *Sphaerium* clams, *C. isostomum* in *Sphaerium*, *Leuceruthrus micropteri* in *Goniobasis* and *Pleurocera* snails, *Rhipidocotyle septpapillata* in *Lampsilis* clams, *Phylodistomum caudatum* in *Musculium* clams, and *Alloglossidium corti* in *Helisoma* snails.

LITERATURE CITED

ANDERSON, M. G., AND F. M. ANDERSON. 1967. The life histories of *Proterometra albacauda* and *Proterometra septimae*, sp. n. (Trematoda: Azygiidae) and a redescription of *Proterometra catenaria* Smith, 1934. J. Parasitol. 53 (1):31–37.

BAILEY, R. M., J. M. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of the common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. 6:1–149.

BANGHAM, R. V., AND J. R. ADAMS. 1954. A survey of the parasites of freshwater fishes from the mainland of British Columbia. J. Fish. Res. Bd. Can. 11(6):673–708.

CABLE, R. M. 1935. *Cercaria kentuckiensis* n. sp., first representative of the Vivax group known to occur in the United States. J. Parasitol. 21:441.

DOBROVOLNY, G. G. 1939a. Life history of *Plagioporus sinitsini* Mueller, and embryology of new cotylocerous cercariae (Trematoda). Trans. Amer. Microsc. Soc. 58(2):121–155.

———. 1939b. The life history of *Plagioporus*

lepomis, a new trematode from fishes. J. Parasitol. 25(6):461–470.

FISCHTHAL, J. H. 1947. Parasites of northwest Wisconsin fishes. I. The 1944 survey. Trans. Wis. Acad. Sci. Arts Lett. 37:157–220.

HARLEY, J. P., AND T. L. KEEFE. 1971. Helminth parasites of four species of sunfishes (Centrarchidae) from Lake Wilgreen in Kentucky. Trans. Ky. Acad. Sci. 32(3–4):71–74.

HOFFMAN, G. L. 1953. Parasites of fish of Turtle River, North Dakota. Proc. N. D. Acad. Sci. 7:12–19.

————. 1967. Parasites of North American freshwater fishes. Univ. California Press, Berkeley, Cal. 485 pp.

MANTER, H. W. 1969. Pp. 93–104. *In* G. D. Schmidt (Ed.). Problems in systematics of trematode parasites. University Park Press, Baltimore, Md.

PATTON, S. 1973. Some studies of *Leuceruthrus micropteri* (Marshall and Gilbert, 1905). Ass. Southeast. Biol. Bull. VI. 20(2):74–75.

PEARSE, A. S. 1924. Observations on parasitic worms from Wisconsin fishes. Trans. Wis. Acad. Sci. Arts Lett. 21:147–160.

PETERS, L. E. 1957. An analysis of the trematode genus *Allocreadium* (Looss) with the description of *Allocreadium neotenicum* sp. nov. from water beetles. J. Parasitol. 43(2): 136–142.

PRITCHARD, M. H. 1966. A revision of the genus *Podocotyle* (Trematoda: Opecoelidae). Zool. Jahrb. Syst. 93:158–172.

VAN CLEAVE, H. J., AND J. F. MUELLER. 1932. Parasites of the Oneida Lake fishes. Part I. Descriptions of new genera and new species. Bull. N. Y. St. Coll. For., Roosevelt Wild Life Ann. 3(1):5–71.

————, AND ————. 1934. Parasites of Oneida Lake fishes. Part III. A biological and ecological survey of the worm parasites. Bull. N. Y. St. Coll. For., Roosevelt Wild Life Ann. 3(3–4):161–334.

WHITE, G. E. 1974. Parasites of the common white sucker (*Catostomus commersoni*) from the Kentucky River drainage. Trans. Amer. Microsc. Soc. 93(2):280–282.

WOODHEAD, A. E. 1930. Life history studies on the trematode family Bucephalidae. II. Trans. Amer. Microsc. Soc. 49(1):1–17.

YAMAGUTI, S. 1958. Systema Helminthum. Interscience Publ., New York, N. Y. Vol. 1. 1,575 pp.

————. 1971. Synopsis of digenetic trematodes of vertebrates. Keigaku, Tokyo, Japan Vol. 1. 1,074 pp.

Preparation of Monobromoisoquinolines

JERRY L. BUTLER, FORREST L. BAYER, AND MARSHALL GORDON
Department of Chemistry and Geology, Murray State University, Murray, Kentucky 42071

ABSTRACT

During the course of other investigations, it became necessary to synthesize the 1-, 3-, 4-, 5-, 6-, 7-, and 8-bromoisoquinolines. 6- and 7-Bromoisoquinoline are new compounds. Details of the preparation of each isomer include kinds and amounts of chemicals used and the various steps taken. Each compound was purified by preparative gas chromatography. Mass spectra were obtained using a Varian Model HC-7 single focusing spectrometer. Structural identities of isomers were confirmed with infrared and nuclear magnetic resonance spectra.

INTRODUCTION

The bromination of isoquinoline in the gaseous phase at 450 C gives small amounts of 1-bromoisoquinoline, as well as much carbonized material (Jansen and Wibaut 1937). The tendency toward bromination at the position α, rather than β, to the ring nitrogen with increase in the reaction temperature is seen to be the same with isoquinoline as with quinoline. It is possible that bromine atoms are the reacting species at the higher temperatures.

4-Bromoisoquinoline is obtained by heating the perbromide of isoquinoline or its salts (Edinger and Bossung 1891, Bergstrom and Rodda 1940, Craig and Cass 1942). No completely satisfactory explanation of the bromination of isoquinoline on the 4-position has been presented. In isoquinoline, as well as quinoline, electrophilic substitution would be expected to take place most readily on the 5- or 8-positions; however, in both compounds, bromination occurs not in the benzenoid ring but in the pyridinoid ring, β to the nitrogen. An explanation involving the attack of bromine radicals rather than positively charged bromine ions is not satisfactory, since a radical attack is expected to occur more readily at the 1-position of isoquinoline than at the 4-position. Eisch's bridged bromonium ion transition state cannot be extended to the isoquinoline molecule, since substitution occurs at the 4-position and this position does not have adjacent carbons with low π-electron densities (Eisch 1962).

Competitive experiments have shown that the 5-position in isoquinoline is 25 times more reactive than in quinoline (Dewar and Maitlis 1957). In spite of the fact that isoquinoline appears more reactive than quinoline, very few substituted isoquinolines are known. The preparation of isoquinoline compounds is somewhat stifled because there are no ring closure procedures which even come close to the usefulness of the Skraup synthesis in preparing substituted quinolines.

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MATERIALS AND METHODS

Each compound prepared was purified by preparative gas chromatography using a column packed with 10 percent QF-1 coated onto Chromosorb G, AW, 60/70 mesh.

Mass spectra for purposes of identification were obtained using a Varian, Model HC-7 single focusing mass spectrometer. Pure samples were injected by means of a direct insertion probe and were sufficiently volatile under 75 C (5×10^6 torr) to produce good spectra. All spectra were obtained using an ionization voltage of 70 ev, resolution of at least 1200, and a filament current of 1000 μÅ. Publication of a detailed study of the mass spectra is planned.

To further confirm the structural iden-

tities of the bromoisoquinoline isomers, infrared and nuclear magnetic resonance spectra were obtained. All infrared spectra were obtained on a Perkin–Elmer, Model 137 Spectrophotometer. Spectra of all samples were obtained in the neat form. Even though many of the compounds are solid at room temperature, their low melting points permitted each to be run as liquids between heated potassium bromide plates. Nuclear magnetic resonance spectra were obtained using a Varian A60-A and a JEOL 100 MH_z nmr spectrometer.

Preparation of Monobromoisoquinoline Isomers

Preparation of 1-Bromoisoquinoline

1-Isoquinolinol (isocarbostyril) (5.0 g, 0.034 mole) and phosphorus pentabromide (17.2 g, 0.04 mole) were mixed by mechanical stirring, heated to 120 C for 15 min, and then to 150 C for 30 min. Upon cooling, water was added to the solidified mixture to hydrolyze any unreacted phosphorus bromides while dissolving the solid mass. The mixture was made basic with sodium hydroxide and filtered. The precipitate was dried and sublimed (80 C/0.05 mm) which gave 6.81 g (94.2%) of 1-bromoisoquinoline as white crystals, mp 96–97 C.

Preparation of 3-Bromoisoquinoline

(a) Preparation of 1,3-Dibromoisoquinoline. 1,3-Isoquinolinediol (8.05 g, 0.05 mole) and phosphorus pentabromide (51.6 g, 0.12 mole) were refluxed with mechanical stirring for 5 hours. After cooling, the black pasty mixture was poured onto cracked ice and made basic with sodium hydroxide. After standing at room temperature for 13 hours, the mixture was filtered and the precipitate dried. The dried precipitate was refluxed with absolute ethanol and filtered to remove inorganic material. The filtrate, upon removal of the solvent, gave crude 1,3-dibromoisoquinoline which was recrystallized from methanol giving 7.2 g (50.2%) of 1,3-dibromoisoquinoline as white crystals, mp 144–146 C (Osburn et al. 1956, mp 147–147.5 C).

(b) Preparation of 3-Bromoisoquinoline. 1,3-Dibromoisoquinoline was reduced by the method of Haworth and Robinson (1948). In a 50-ml three-necked, round-bottomed flask equipped with a reflux condenser, mechanical stirrer, and thermometer, 1,3-dibromoisoquinoline (3.0 g), red phosphorus (powdered, 1.0 g), and acetic acid (glacial, 14 ml) were refluxed for 6 hours. The cooled mixture was basified with aqueous sodium hydroxide and steam distilled. The material, which solidified in the initial runnings, was collected, dissolved in 2 N hydrochloric acid, and filtered from the insoluble 1,3-dibromoisoquinoline. The filtrate was basified with aqueous sodium hydroxide and filtered. The dried precipitate was sublimed (45 C/0.15 mm) which gave 0.87 g (40.4%) of 3-bromoisoquinoline as colorless needles, mp 62–63 C (Osburn et al. 1956, mp 63–64 C).

Preparation of 4-Bromoisoquinoline

Isoquinoline (38.7 g, 0.3 mole) was dissolved in concentrated (48%) hydrobromic acid (25 ml) and evaporated almost to dryness. Liquid bromine (48 g, 0.3 mole) was added slowly, and the mixture heated for 7 hours at 180 C. Upon cooling, the solution was made basic with aqueous sodium hydroxide and steam distilled. The distillate was extracted with benzene and the solvent removed to leave a brown oil which was vacuum distilled giving 2 fractions. The second fraction of 16.1 g boiled at 122–125 C (4.5 mm) and consisted chiefly of 4-bromoisoquinoline. The crude product was sublimed (30 C/6.0 mm) which gave 15.2 g (24.3%) of 4-bromoisoquinoline as white needles, mp 39–40.5 C (Craig and Cass 1942, mp 38–39 C).

Preparation of 5-Bromoisoquinoline (Robinson 1947a)

(a) 5-Aminoisoquinoline (3.0 g) in concentrated (48%) hydrobromic acid (12 ml) and water (10 ml) was diazotized at 0 C with sodium nitrite (1.5 g) in water (10 ml). The diazonium solution was slowly added to a stirred solution of cuprous bromide (3.6 g) in hydrobromic acid (25 ml) at

75 C. After 2 hours at room temperature, the solution was basified and extracted with diethyl ether. After removal of the solvent, the residue was sublimed (75 C/0.10 mm) which gave 2.78 g (64.1%) of 5-bromoisoquinoline as white needles, mp 83–83.5 C (Osburn et al. 1956, mp 82–84 C).

(b) 5-Bromoisoquinoline was also prepared by the method of Gordon and Pearson (1964). Isoquinoline (54.5 g, 0.42 mole) was added dropwise to stirred anhydrous aluminum chloride (113.4 g, 0.85 mole) in a three-necked flask equipped with a stirrer, condenser, and a dropping funnel. Considerable heat was evolved and the mixture passed through a pasty transition phase, needing manual stirring, before the complex was formed completely. The temperature was maintained at approximately 75 C until all of the isoquinoline was added. After all of the isoquinoline was complexed, liquid bromine (44.8 g, 0.28 mole) was added in the vapor phase over a period of 8 hours. The mixture was heated to 100 C and stirred for an additional hour. The black fluid mixture was allowed to cool to room temperature and poured carefully onto hand stirred cracked ice. The acidic aqueous solution was filtered at 75 C to remove all insoluble material. The acidic filtrate was made strongly basic by adding concentrated aqueous sodium hydroxide. The addition was done rapidly since aged precipitates of aluminum hydroxide do not dissolve readily in alkali. The basic solution was extracted with diethyl ether and the solvent removed. The residue was distilled under vacuum giving 40.46 g (57.2%) of 5-bromoisoquinoline, bp 108–112 C (0.05 mm).

Preparation of 5-, 6-, 7-, and 8-Bromoisoquinoline

All the benzenoid ring bromoisoquinolines were prepared according to the procedure given by Tyson (1939) for a modified Pomeranz-Fritsch reaction. No physical constants were given by him as the compounds were converted directly to the carboxylic acids.

(a) Preparation of the Bromobenzalaminoacetals. Aminoacetal (aminoacetaldehyde diethyl acetal) was mixed in excess (15%) with the required amount of the desired bromobenzaldehyde, heated for 2 hours on a steam bath and allowed to cool. Water which formed from this condensation was removed by an alternate addition and distillation of benzene. The crude Schiff base was distilled under reduced pressure giving colorless liquids in each case. Essential information on the preparation of the 3 isomeric bromobenzaliminoacetals is given in Table 1.

TABLE 1.—PREPARATION OF 3 ISOMERIC BROMOBENZALIMINOACETALS

Bromobenzaldehyde used, g	Acetal Yield, g	Bp of Acetal °C	Bp of Acetal mm	% Yield
14, ortho-	18.0	118–123	0.15	81.1
14, meta-	19.3	134–139	0.45	85.7
14, para-	21.2	160–164	4.00	93.3

In each case the bromobenzaliminoacetals were sealed in ampoules under a nitrogen atmosphere to prevent oxidation before use.

(b) Preparation of the Bromoisoquinolines. The bromobenzaliminoacetal was added to 9 times its weight of concentrated sulfuric acid maintained at 0–5 C. This mixture was added with mechanical stirring, during 10 min, to a mixture of 10 g of concentrated sulfuric acid and 20 g of phosphoric anhydride maintained at 160 C. Stirring and heating were continued for 35 additional min. The mixture, while still acidic, was steam distilled to remove any aldehyde present as a result of hydrolysis of the unreacted Schiff base. The mixture was made basic with aqueous sodium hydroxide and steam distilled a second time to remove the bromoisoquinoline. The workup of each isomer was carried out as given below.

(1) 6-Bromoisoquinoline (starting with p-bromobenzaldehyde)

The distillate was cooled to 5 C and the white solid material filtered. The crude product was dried in a vacuum desiccator and sublimed (45 C/0.001 mm) which gave 6-bromoquinoline as colorless crystals

(37% yield), mp 81 C (Gordon 1964, unpublished doctoral dissertation, Vanderbilt University, Nashville, Tennessee, mp 67 C).

Anal.

Calcd. for C_9H_6NBr: C, 51.92; H, 2.88.
Found: C, 51.84; H, 2.93.

(2) 8-Bromoisoquinoline (starting with o-bromobenzaldehyde)

The distillate was cooled to 5 C and the white solid material filtered. The crude product was dried in a vacuum desiccator and sublimed (60 C/0.2 mm) which gave 8-bromoisoquinoline as white crystals (21% yield), mp 85–87 C.

(3) Mixture of 5- and 7-Bromoisoquinoline (starting with m-bromobenzaldehyde)

The distillate was extracted with diethyl ether and the ether removed leaving a brownish oil which solidified upon standing. An attempt to separate the isomers by fractional crystallization of the mixture of nitrates obtained by dissolving the free bases in 1 N nitric acid failed. The highest melting fraction (mp 153–155 C) was way short of the authentic 5-bromoisoquinoline nitrate, mp 196–198 C.

Preparation of 7-Bromoisoquinoline

(a) Preparation of N-Formyl-β-phenethylamine. β-Phenethylamine (100 g, 0.826 mole) was heated with formic acid (100 ml, 87%) on a steam bath for 2 hours. The formic acid was evaporated in vacuum and the procedure repeated. The resulting crude formylamino compound still contained some amine which was removed by extraction with dilute acetic acid. The crude product was distilled (bp 152–155 C, 0.5 mm) giving the N-formyl-β-phenethylamine (97 g, 77.4%) as a colorless oil. Infrared analysis exhibited the characteristic stretching bands for the N–H and C=O along with the band for a monosubstituted benzene ring.

(b) Preparation of 3,4-Dihydroisoquinoline (Synder and Werber 1950). N-Formyl-β-phenethylamine (95 g, 0.638 mole) and PPA (150 g) prepared as given by *Reagents for Organic Synthesis*, Vol. I, were placed in a 250-ml flask. The solution was heated at 145 C with efficient stirring for 2 hours. The hot reaction mixture was decomposed with ice; concentrated hydrochloric acid (20 ml) was added; and the neutral components extracted with diethyl ether. The aqueous acidic solution was neutralized with concentrated aqueous ammonia and the liberated oil extracted with benzene. After drying (Na_2SO_4) and removal of the benzene, the residual oil was distilled under vacuum (bp 115–120 C, 0.5 mm) giving the 3,4-dihydroisoquinoline in 67.1 percent yield as a colorless oil. The picrate salt, after 2 recrystallizations from 95 percent ethanol, melted at 175–176 C (Synder and Werber 1950, mp 176–177 C; Späth et al. 1930, mp 175–176 C).

(c) Preparation of 7-Nitro-3,4-Dihydroisoquinoline (McCoubrey and Mathieson 1951). 3,4-Dihydroisoquinoline (10 g) in concentrated sulfuric acid (25 ml) was added to potassium nitrate (10 g) in concentrated sulfuric acid (20 ml), the temperature being kept at 0 C. This solution was allowed to attain room temperature, then was heated with stirring at 60 C for 4 hours. The solution was poured onto cracked ice and neutralized with concentrated aqueous ammonia. The brown precipitate was filtered, dried, and used directly in the next step.

(d) Preparation of 7-Nitroisoquinoline (McCoubrey and Mathieson 1951). 7-Nitro-3,4-dihydroisoquinoline, as prepared above, was refluxed with decalin (150 ml) containing palladium on charcoal (3 g, 5%) for 2.5 hours. After cooling, an equal volume of chloroform was added and the mixture extracted 3 times with 400-ml portions of 2 N hydrochloric acid. The acidic extract was evaporated to half its original volume and neutralized with solid potassium hydroxide, with ice cooling. The brown precipitate was filtered, dried, and sublimed (150 C/0.1 mm) giving 7-nitroisoquinoline (1.42 g) as pale yellow needles, mp 178 C (McCoubrey and Mathieson 1951, mp 177–178 C).

(e) Preparation of 7-Aminoisoquinoline. A solution of 7-nitroisoquinoline (1.4 g, 8.04 moles) in absolute ethanol (100 ml) containing palladium on charcoal (2.0 g,

5%) was reduced by hydrogen using a Parr hydrogenator at room temperature. After 1 hour, the pressure had dropped to a constant value which was 2.5 psi less than the starting value. The calculated amount of hydrogen for this reduction was 1.6 psi. The solution was filtered and the ethanol evaporated. The residue was sublimed (150 C/0.1 mm) which gave 7-aminoisoquinoline (1.07 g, 92.9%) as pale yellow prisms, mp 202-203 C (McCoubrey and Mathieson 1951, mp 201–202 C).

(f) Preparation of 7-Bromoisoquinoline. 7-Aminoisoquinoline (1.0 g) in concentrated (48%) hydrobromic acid (5 ml) and water (5 ml) was diazotized at 0 C with sodium nitrite (0.5 g) in water (5 ml). The resulting diazonium solution was added slowly to a stirred solution of cuprous bromide (1.2 g) in concentrated (48%) hydrobromic acid (10 ml) at 75 C. After 20 hours at room temperature, the solution was basified and filtered. The filtrate was extracted with chloroform and the chloroform removed. The resulting residue was combined with the precipitate and sublimed (45 C/0.15 mm) which gave 7-bromoisoquinoline (0.67 g, 49.1%) as colorless crystals, mp 70 C.

Anal.
Calcd. for C_9H_6NBr:
C, 51.92; H, 2.88; Br, 38.46.
Found: C, 51.92; H, 2.87; Br, 38.59.

Preparation of 8-Bromoisoquinoline

(a) Preparation of 5-Bromo-8-nitroisoquinoline (Osburn et al. 1956). Potassium nitrate (4.8 g) in concentrated sulfuric acid (40 ml) was added over a period of 15 min to 5-bromoisoquinoline (8.2 g) in concentrated sulfuric acid (35 ml) at 20 C. After 4 hours of stirring at room temperature, the solution was poured onto cracked ice and made basic with aqueous ammonia. The resulting yellow precipitate was filtered and dried. Recrystallization from an ethanol–water solvent pair gave 10.3 g (99%) of 5-bromo-8-nitroisoquinoline as yellow needles, mp 138.5–140 C (Osburn et al. 1956, mp 139–141 C).

(b) Preparation of 8-Aminoisoquinoline (Gordon and Pearson 1964). A solution of ammonium acetate (20 g) and 5-bromo-8-nitroisoquinoline (15.0 g) in acetic acid (glacial, 300 ml) containing 8.0 g of 5 percent palladium on calcium carbonate (Englehard Industries, Inc., Newark, N. J.) was reduced by hydrogen using a Parr hydrogenator at room temperature. Hydrogen was absorbed rather rapidly (45 min) but the process was continued for 15 hours. A total of 19.5 psi (calcd. 16.5 psi) of hydrogen was absorbed. The solution was filtered to remove the catalyst, poured onto cracked ice, and made basic with aqueous sodium hydroxide. The precipitate which formed was filtered and dried. The filtrate was extracted with chloroform and the chloroform removed. The precipitate and residue from the chloroform extract were combined and sublimed (130 C/0.15 mm) which gave 6.75 g (79.7%) of 8-aminoisoquinoline as pale yellow crystals, mp 173–174 C (Osburn et al. 1956, mp 171–172 C; Gordon and Pearson 1964, mp 170–172 C; Robinson 1947b, mp 174 C; Ahmad and Hey 1961, mp 173–174 C).

(c) Preparation of 8-Bromoisoquinoline. 8-Aminoisoquinoline (2.0 g) in concentrated (48%) hydrobromic acid (12 ml) and water (12 ml) was diazotized at 0 C with sodium nitrite (1.2 g) dissolved in water (10 ml). The resulting diazonium solution was slowly added to a stirred solution of cuprous bromide (2.4 g) in concentrated hydrobromic acid (30 ml) at 75 C. After 12 hours at room temperature, the solution was made basic with aqueous sodium hydroxide and filtered. The dried precipitate was sublimed (55 C/0.1 mm) which gave 2.43 g (84.7%) of 8-bromoisoquinoline as white crystals, mp 86–87 C.

RESULTS AND DISCUSSION

1-Bromoisoquinoline was prepared by the action of phosphorus pentabromide on 1-hydroxyisoquinoline. The desired product was obtained in the pure form in a 94 percent yield. The desirability of reactions of this type is that the bromo- compounds are easily obtained in the pure form. The melting points of the hydroxy-compounds are greater than 200 C which

permits easy removal of the bromo- compounds by fractional sublimation.

Isoquinolines with only a substituent in the 3-position are rare, however, 3-bromoisoquinoline was prepared by first synthesizing 1,3-dibromoisoquinoline from the 1,3-dihydroxy- compound. The 1,3-dibromo- compound was then reduced to give the 3-bromoisoquinoline in a 40 percent yield.

4-Bromoisoquinoline was prepared by the addition of bromine to isoquinoline hydrobromide. The reaction was lengthy and gave the desired product in a low yield (24%). The procedure of Kress and Costantino (1973) gave 3-bromoquinoline in a very high yield and would most likely be best suited for the preparation of 4-bromoisoquinoline.

5-Bromoisoquinoline was prepared by 3 different reactions. The ring closure reactions for preparing benzenoid substituted isoquinolines are noted for their low yields. A ring closure reaction, starting with m-bromobenzaldehyde, gave a mixture of 5- and 7-bromoisoquinoline in a very low yield. This reaction is not suited for authentic sample preparation because of its low yields and the difficulty encountered in separating the isomeric products. 5-Aminoisoquinoline, by the Sandmeyer reaction, gave the desired product in a 64 percent yield. Also, the swamping catalyst technique employed by Gordon and Pearson (1964) gave 5-bromoisoquinoline in a 57 percent yield.

6-Bromoisoquinoline was prepared by a ring closure reaction reported by Tyson (1939). No physical constants were given by him as the compounds were converted directly to the corresponding carboxylic acid. The procedure, although lengthy, gave the desired product in a 37 percent yield.

7-Bromoisoquinoline was prepared as prepared as previously described giving a mixture of 5- and 7-bromoisoquinoline. However, the yield was very low and attempts to separate the isomeric products failed. Thus, 7-bromoisoquinoline was prepared by a Sandmeyer reaction on 7-aminoisoquinoline.

LITERATURE CITED

AHMAD, Y., AND D. H. HEY. 1961. 8-Phenylisoquinolines. J. Chem. Soc. 3882–3885.

BERGSTROM, F. W., AND J. H. RODDA. 1940. The preparation and properties of some 4-substituted isoquinolines. J. Amer. Chem. Soc. 62: 3030–3032.

CRAIG, J. J., AND W. E. CASS. 1942. Derivatives of aminoisoquinolines. J. Amer. Chem. Soc. 64:783–784.

DEWAR, M. J. S., AND P. M. MAITLIS. 1957. Electrophilic substitution. Part XI. Nitration of some six-membered nitrogen-heterocyclic compounds in sulphuric acid. J. Chem. Soc. 2521–2528.

EDINGER, A., AND BOSSUNG. 1891. J. Prakt. Chem. 43(2):190.

EISCH, J. J. 1962. Aza-aromatic substitution. I. The selective bromination of the quinoline nucleus. J. Org. Chem. 27:1318–1323.

GORDON, M., AND D. E. PEARSON. 1964. The swamping catalyst effect. VI. The halogenation of isoquinoline and quinoline. J. Org. Chem. 29:329–332.

HAWORTH, R. D., AND S. ROBINSON. 1948. Synthetic antimalarials. Part XXVII. Some derivatives of phthalazine, quinoxaline, and isoquinoline. J. Chem. Soc. 777–782.

JANSEN, H. E., AND J. P. WIBAUT. 1937. The bromination of quinoline, isoquinoline, thiazole and benzothiazole in the gaseous phase. Rec. Trav. Chim. 56:699–708.

KRESS, T. J., AND S. M. COSTANTINO. 1973. Selective brominations in nitrobenzene. A convenient synthesis of 3-bromoquinoline, 4-bromoisoquinoline, and 4-phenyl-5-bromopyrimidine. J. Hetero. Chem. 10:409–410.

MCCOUBREY, A., AND D. W. MATHIESON. 1951. Isoquinolines. III. The nitration of 3,4-dihydro- and 1,2,3,4-tetrahydro-isoquinolines. J. Chem. Soc. 2851–2853.

OSBURN, A. R., K. SCHOFIELD, AND L. N. SHORT. 1956. Studies of the aminoisoquinolines, -cinnolines, and -quinazolines. J. Chem. Soc. 4191–4206.

ROBINSON, R. A. 1947a. 5-(γ-Diethylaminopropylamino)-isoquinoline. J. Amer. Chem. Soc. 69:1942–1943.

————. 1947b. 7-(γ-Diethylaminopropylamino)-isoquinoline. J. Amer. Chem. Soc. 69: 1944.

SPÄTH, D., F. BERGER, AND W. KUNTARA. 1930. Synthesis of isoquinoline derivatives. Ber. 63B:134–141.

SYNDER, H. R., AND F. X. WERBER. 1950. Polyphosphoric acid as a dehydrating agent. I. The cyclodehydration of some α-acylamino-β-arylopropionic acids. J. Amer. Chem. Soc. 72:2962–2965.

TYSON, F. T. 1939. Synthesis of isoquinoline acids. J. Amer. Chem. Soc. 61:183–185.

The Big Clifty Prairie, a Remnant Outlier of the Prairie Peninsula, Grayson County, Kentucky

William S. Bryant
Department of Biology, Thomas More College, Ft. Mitchell, Kentucky 41017

Abstract

The Big Clifty Prairie, an outlier of the Prairie Peninsula, contains 118 species of plants representing 44 families. *Andropogon scoparius* and *A. gerardi* are the dominant grasses, while forbs include members of the Compositae, Leguminosae, Labiatae, and Cyperaceae. Woody plants are confined to the prairie edge. Minor disturbances to the prairie have occurred as evidenced by numerous weedy species. The overall prairie community is maintaining itself within a forested region, partially because of local soil conditions.

Introduction

In Kentucky, a vegetational type that has received little scientific attention is the prairie. That prairies once occupied a significant area of land in the state is well documented. Transeau (1935) in his map of the Prairie Peninsula, showed prairies as occurring in a narrow band across western and west-central Kentucky (Fig. 1). McInteer (1946) estimated that the Big Barrens prairies ranged from 8,000 to 9,600 km^2. Garman (1925) stated that the great meadows (prairies) in Kentucky had largely disappeared with tall grasses being replaced by weeds. Today, only small, scattered remnants of the original prairie remain.

Previous workers in the Kentucky prairies, Garman (1925), Sauer (1927), Dicken (1935), McInteer (1942, 1946), and Braun (1950) described certain aspects of the prairies, however, much of those works centered on the possible origins of the grasslands. Except for Garman (1925), who discussed the resemblance of the Kentucky prairies to those in Illinois, and McInteer (1946), who gave a brief list of tree species, no thorough vegetational descriptions have been given.

The present paper is an attempt to describe the vegetational and floral composition of one small prairie outlier of the Prairie Peninsula in Kentucky. Neither Transeau (1935) nor McInteer (1946) showed prairies in Grayson County, but they did show extensive prairie tracts in Hardin County. The Big Clifty Prairie lies a few hundred meters west of the Hardin County line.

Acknowledgments

Special thanks are due Dr. Willem Meijer, University of Kentucky, who aided with plant identifications.

Description of Study Area

The Big Clifty Prairie is on a nearly level plain, approximately 4.0 km (2.5 miles) east of the village of Big Clifty, Grayson County. The prairie, less than 1 ha in extent, occurs as a narrow strip within the rights-of-way of US Highway 62 and the Illinois Central Railroad. Because of that protected location, the prairie has not been broken by the plow.

The northeastern section of Grayson County, in which Big Clifty Prairie lies, is in the Pennyroyal physiographic area. The underlying rock is Big Clifty Sandstone, a member of the Golconda Formation. The soil is Sadler Silt Loam, a loess soil underlain with a slowly permeable fragipan (Whitaker et al. 1972).

The climate of Grayson County is temperate; the average annual temperature is 14.4 C, and the annual precipitation is 122.7 cm (Whitaker et al. 1972).

Methods

Twenty-five 1×1-m quadrats, spaced at 10-m intervals, were established along a straight-line transect through the center

FIG. 1. Map of Kentucky showing the approximate location of the Prairie Peninsula. The location of the Big Clifty Prairie, an outlier, is indicated by an X. (Modified from Transeau 1935.)

of the prairie. The presence of plant species in each quadrat was recorded. Frequencies of occurrence were then determined.

Plants were collected on numerous occasions from 1968 to 1976. Voucher specimens of many of the plants are held in my personal collection.

PLANTS OF BIG CLIFTY PRAIRIE

A total of 118 species of plants representing 44 families was collected from the prairie and identified. The dominant families were the Compositae with 24 species; Gramineae, 13; Leguminosae, 12; Cyperaceae, 8; and Labiatae, 5 (Table 1).

Andropogon scoparius and *A. gerardi*, with frequencies of 100 and 44, respectively, were the dominant prairie grasses (Table 2). Native forbs *Strophostyles umbellata* (68), *Solidago missouriensis* (48), *Aster* sp. (48), *A. patens* (28), *Potentilla simplex* (28), *Pycnanthemum flexuosum* (20), *Cassia fasciculata* (12), and *Parthenium integrifolium* (12) were abundant. Members of various genera of sedges and rushes, *Carex*, *Scleria*, *Cyperus*, and *Eleocharis*, also were abundant. Invader species, *Smilax rotundifolia*, *Achillea millefolium*, *Chrysanthemum leucanthemum*, and *Poa pratensis*, indicated some degree of disturbance as having occurred. Native species and noninvaders outnumbered the invaders.

Shrubs and small trees, *Corylus americana*, *Salix humilis*, *S. nigra*, *Nyssa sylvatica*, *Diospyros virginiana*, and *Rhus copallina*, were abundant in a ditch at the edge of the railroad. Oaks, *Quercus stellata*, *Q. velutina*, and *Q. marilandica*, were represented by a few individuals.

No analysis of soil was attempted, however, a thorough analysis of the Sadler Silt Loam was presented by Whitaker et al. (1972).

DISCUSSION

In his discussion of the xerothermic period, Gleason (1923) pointed to one of its effects as being the extension of the prairie flora to the east. He cited as evidence of this the relict prairie colonies in the eastern deciduous forest region. Transeau (1935) stated that distinctive prairie flora and isolated typical prairie communities occur as far south as Kentucky and Tennessee. McInteer (1946) noted that the prairies in Kentucky were once extensive, but those once extensive tracts have all but disappeared (Meijer 1970).

The location and subsequent ecological study of those relicts is of utmost importance since prairies have not been well defined in Kentucky. In Wisconsin, Curtis

TABLE 1.—A PRELIMINARY LIST OF VASCULAR PLANTS COLLECTED AT BIG CLIFTY PRAIRIE, GRAYSON COUNTY, KENTUCKY. NOMENCLATURE FOLLOWS FERNALD (1950)

ANACARDIACEAE
Rhus copallina
APOCYNACEAE
Apocynum cannabinum
ASCLEPIDACEAE
Asclepias incarnata
A. syriaca
A. verticillata
BETULACEAE
Corylus americana
CALLITRICHACEAE
Callitriche deflexa
CAMPANULACEAE
Specularia perfoliata
CAPRIFOLIACEAE
Lonicera japonica
CARYOPHYLLACEAE
Dianthus armeria
Saponaria officinalis
ASTERACEAE
Achillea millefolium
Aster patens
Aster sp.
Bidens sp.
Chrysanthemum leucanthemum
Coreopsis tripteris
Erigeron annus
Eupatorium altissimum
E. serotinum
Gnaphalium purpureum
Helenium flexuosum
Helianthus hirsutus
Helianthus mollis
Lactuca canadensis
Parthenium integrifolium
Ratibida pinnata
Rudbeckia hirta
Seriocarpus asteroides
Silphium integrifolium
S. perfoliatum
Solidago missouriensis
S. juncea
Tragopogon dubius
Vernonia missurica
CORNACEAE
Nyssa sylvatica
CYPERACEAE
Carex complanata
C. frankii
C. vulpinoidea
Cyperus ovularis
Cyperus sp.
Eleocharis tenuis
Scirpus atrovirens
Scleria pauciflora
EBENACEAE
Diospyros virginiana
EUPHORBIACEAE
Euphorbia corollata
E. supina
FAGACEAE
Quercus marilandica
Q. stellata
Q. velutina
GENTIANACEAE
Sabatia angularis
GERANIACEAE
Geranium carolinianum
POACEAE
Andropogon gerardi
A. scoparius
Bromus tectorum
Elymus virginicus
Festuca elatior
Panicum nitidum
Paspalum sp.
Phleum pratensis
Poa compressa
P. pratensis
Secale cereale
Setaria lutescens
Sorgastrum nutans
HYPERICACEAE
Ascyrum hypericoides
Hypericum sphaerocarpum
JUNCACEAE
Juncus sp.
LAMIACEAE
Lycopus virginicus
Prunella vulgaris
Pycnanthemum flexuosum
Salvia lyrata
Scutellaria parvula
LAURACEAE
Sassafras albidum
LEGUMINOSAE
Cassia fasciculata
Desmanthus illinoensis
Desmodium ciliare
D. laevigatum
D. sessilifolium
Lespedeza virginica
Medicago lupalina
Melilotus alba
Psoralea psoralioides
Strophostyles umbellata
Tephrosia virginiana
Trifolium procumbens
LILIACEAE
Hemerocallis fulva
Smilax rotundifolia
LINACEAE
Linum virginianum
LOBELIACEAE
Lobelia puberula
L. spicata
ONOGRACEAE
Ludwigia alternifolia
ORCHIDACEAE
Spiranthes vernalis
OXALIDACEAE
Oxalis stricta
PLANTAGINACEAE
Plantago aristata
P. lanceolata
PLATANACEAE
Platanus occidentalis
POLAMONIACEAE
Phlox maculata
POLYGALACEAE
Polygala sanguinea
P. verticillata
POLYGONACEAE
Rumex acetosella
R. conglomeratus
RANUNCULACEAE
Anemone virginiana
RHAMNACEAE
Ceanothus americanus
ROSACEAE
Potentilla simplex
Rosa setigera
Rubus flagellaris
RUBIACEAE
Diodia teres
Galium pilosum
SALICACEAE
Salix humilis
S. nigra
SCROPHULARIACEAE
Chaenorrhinum minus
Verbascum thapsus
SOLANACEAE
Physalis sp.
ULMACEAE
Ulmus alata
VERBENACEAE
Verbena simplex
VIOLACEAE
Viola sagittata
VITACEAE
Vitis cinerea

TABLE 2.—FREQUENCY OCCURRENCE OF PLANT SPECIES AT BIG CLIFTY PRAIRIE, GRAYSON COUNTY, KENTUCKY, BASED ON 25 1×1-M QUADRATS

Species	Frequency
Andropogon scoparius	100
Smilax rotundifolia	72
Strophostyles umbellata	68
Chrysanthemum leucanthemum	56
Achillea millefolium	56
Solidago missouriensis	48
Aster sp.	48
Andropogon gerardi	44
Panicum nitidum	36
Aster patens	32
Scleria pauciflora	28
Potentilla simplex	28
Carex complanata	24
Pycnanthemum flexuosum	20
Poa pratensis	16
Salix humilis	16
Cassia fasciculata	12
Eleocharis tenuis	12
Parthenium integrifolium	12
Rubus flagellaris	12
Anemone virginiana	12
Carex sp.	12
Scutellaria parvula	12
Prunella vulgaris	12
Apocynum cannibidum	8
Polygala sanguinea	8
Lactuca canadensis	8
Cyperus ovularis	8
Linum virginianum	8
Euphorbia corollata	8
Polygala verticillata	8
Desmodium sessilifolium	8
Elymus virginicus	8
Festuca elatior	8
Gnaphalium purpureum	4
Rhus copallina	4
Oxalis stricta	4
Ascelpias verticillata	4
Vitis cinerea	4
Melilotus alba	4
Lobelia puberula	4
Sassafras albidum	4
Salvia lyrata	4
Dianthus armeria	4
Sabatia angularis	4
Nyssa sylvatica	4
Vernonia missurica	4
Cyperus sp.	4

and Greene (1949) found that prairie relicts were on atypical sites, so far as the great bulk of original prairie was concerned, and had persisted because of such locations. They found the relicts that most nearly approached the typical condition on railroad rights-of-way where railroads were laid out on grade through large flat areas of high prairie. Garman (1925) stated that probably few prairies in Kentucky have been exterminated, but were still to be found in bits of waste ground and along railroads and highways. Whether typical or not for Kentucky, the Big Clifty Prairie fits those descriptions.

In their extensive study, Curtis and Greene (1949) found low prairies on poorly drained flat lands to support the highest numbers of species, 179. The Big Clifty Prairie also occupies a flat plain with poor internal drainage resulting from the shallow fragipan. The 118 plant species at Big Clifty Prairie, considering its small size, is quite remarkable. Of the 10 species listed as most likely in low prairies in Wisconsin, 4 were present here. The most characteristic grass at Big Clifty Prairie was *Andropogon scoparius*, but Curtis and Greene listed *A. gerardi* as most characteristic for Wisconsin. McInteer (1946) named the tall bluestem *A. gerardi* as the dominant grass of the Barrens. In southern Illinois, Voigt and Mohlenbrock (1964) found *A. scoparius* to be the most common grass. Since no quantitative studies were performed by the early workers in Kentucky's prairies, and dominance was determined by observation alone, perhaps the large size and conspicuousness of *A. gerardi*, as viewed by the early writers, overshadowed its true place in the prairie association of the Barrens.

In southern Illinois, the railroad and highway rights-of-way are dominated by Indian grass *Sorgastrum nutans* that usually indicates a mild disturbance such as frequent burning (Voigt and Mohlenbrock 1964). Only a few scattered individuals of *S. nutans* were present at Big Clifty Prairie, however, that does not rule out past burning as a type of disturbance. In fact, burning has often been mentioned as one of the primary factors in maintaining prairies. The main disturbance at Big Clifty Prairie is the periodic mowing by highway crews. The clippings are left on the

ground, and undoubtedly produce a smothering effect on some of the more fragile plants. Since no set schedule for mowing is followed from year to year, the plants have most likely been disturbed at most stages of their life cycles. Invader species, like *Smilax rotundifolia, Achillea millefolium, Chrysanthemum leucanthemum,* and *Poa pratensis,* take advantage of such disturbances. Weaver (1968) found that the removal of bluestem by mowing is distinctly advantageous for the growth of bluegrass, both in fall and spring.

The abundance of sedges and rushes was encouraged by the nature of the soil and fragipan. There is a tendency for water to collect in the level areas of the Sadler Silt Loam in both winter and early spring (Whitaker et al. 1972). Garman (1925) also noted that rushes and sedges occurred in wet areas of prairies.

Although several species of trees and shrubs were present near the edge of Big Clifty Prairie, no trees were established in the prairie proper. Garman (1925) and McInteer (1946) mentioned the presence of scattered trees including black jack oak *Quercus marilandica,* dwarf willows *Salix* spp., hazel *Corylus* sp., and sumac *Rhus* spp., as well as wild grapes *Vitis* spp. in the prairies of Kentucky. Those species were primarily near the edge of Big Clifty Prairie. Weaver (1968) reported *Corylus americana* to be an invader at the edge of many prairies in Nebraska. Seedlings of *Salix humilis* were recorded in quadrats, but there were no signs of further establishment after invasion by that species or other woody plants.

The persistence of prairie relicts, such as Big Clifty Prairie, in regions of high rainfall and forest vegetation is due largely to local soil and/or drainage conditions. Wistendahl (1975) stated that the Buffalo Beats Prairie in southeastern Ohio within forest vegetation appeared to be related to local soil characteristics. Garman (1925) also noted the establishment of turf that resisted the penetration of forests. At Big Clifty Prairie, water remains on the soil surface where it is least available, and evaporates before it can be efficiently utilized by plants. Because of this condition and the prairie's protected location, the grasses and forbs have been able to maintain themselves with only minor disturbances since xerothermic times. Further research on Kentucky's prairies is needed before this important ecosystem is eliminated from the state. An all-out effort should be made to locate, preserve, and study the remaining prairie remnants.

LITERATURE CITED

BRAUN, E. L. 1950. Deciduous forests of eastern North America. The Blakiston Co., Philadelphia, Pa. 596 pp.

CURTIS, J. T., AND H. C. GREENE. 1949. A study of relic Wisconsin prairies by the species–presence method. Ecology 30:83–92.

DICKEN, S. N. 1935. The Kentucky barrens. Bull. Geogr. Soc. Phila. 43:42–51.

FERNALD, M. L. 1950. Gray's manual of botany. Eighth Ed. American Book Co., New York, N. Y. 1,632 pp.

GARMAN, H. 1925. The vegetation of the barrens. Trans. Ky. Acad. Sci. 2:107–111.

GLEASON, H. 1923. The vegetational history of the middle west. Ann. Ass. Amer. Geogr. 12:39–85.

MCINTEER, B. B. 1942. The barrens of Kentucky. Trans. Ky. Acad. Sci. 10:7–12.

———. 1946. A change from grassland to forest vegetation in the "Big Barrens" of Kentucky. Amer. Midl. Nat. 35:276–282.

MEIJER, W. 1970. The flora and vegetation of Kentucky as a field for research and teaching. Castanea 35:161–176.

SAUER, C. 1927. Geography of the Pennyroyal. Ky. Geol. Surv. Ser. 6, 25. 30 pp.

TRANSEAU, E. N. 1935. The prairie peninsula. Ecology 16:423–437.

VOIGT, J., AND R. H. MOHLENBROCK. 1964. Plant communities of southern Illinois. Southern Illinois Univ. Press, Carbondale, Ill. 202 pp.

WEAVER, J. E. 1968. Prairie plants and their environment. Univ. Nebraska Press, Lincoln, Nebr. 276 pp.

WHITAKER, O. J., F. R. COX, JR., H. T. CONVERSE, JR., J. L. TAYLOR, J. V. BENTLEY, JR., AND E. H. JACOBS. 1972. Soil survey of Grayson County, Kentucky. USDA Soil Cons. Serv., Washington, D. C. 81 pp.

WISTENDAHL, W. A. 1975. Buffalo Beats, a relict prairie within a southeastern Ohio forest. Bull. Torrey Bot. Club 102:178–186.

External Morphology of Adult Leafhoppers of the Genus *Scaphoideus*

Douglas E. Barnett
Department of Entomology, University of Kentucky, Lexington, Kentucky 40506

Abstract

The external morphology of leafhoppers in the genus *Scaphoideus* is treated. Morphology of the external sclerites and their terminology is discussed and illustrated. The literature pertaining to the origin, morphology, and terminology of the head sclerites and genital structures is treated in detail.

Introduction

Few general works treat the external morphology and terminology of members of the Cicadellidae (DeLong 1926; Evans 1946a, 1947b, 1957; Oman 1949), but complete and intensive studies of the external morphology are few. Further, some confusion exists in the terminology applied to various structures. Earlier, considerable weight was placed on information drawn from morphological studies on related families, especially the Cicadidae. Unfortunately, the transfer of information from related families was not always reliable as Orian (1964) noted after completing work on the morphology of *Abricta ferruginosa*. (Homoptera: Cicadidae). Also, there is considerable variation or modification of structures within the family Cicadellidae.

Most authors, in trying to find a common morphological basis among the orders of insects and an explanation of the extremely diversified structures present, have suggested a change in the morphological nomenclature. Hence a diverse set of terminology exists. The terminology in this paper follows that of the majority of workers currently treating species of cicadellids or favors terminology in use by morphologists. Alternate terms for many structures are also included.

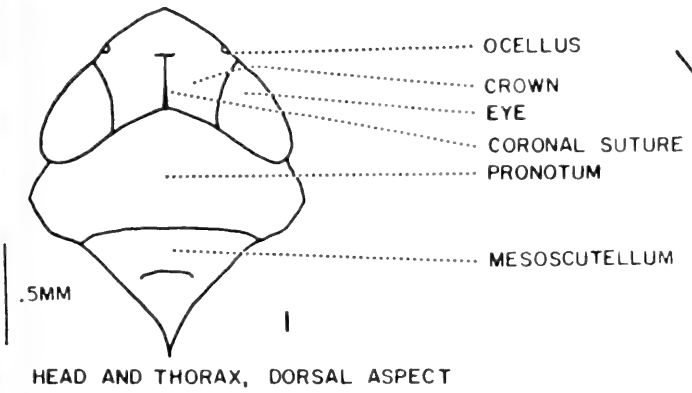
Materials and Methods

Material for study was collected in Kentucky. Various combinations of water, ethyl alcohol, and ethyl ether were tested as the clearing solution. The following solution was best and consisted of 5 ml of ethyl ether, 50 ml of 70 percent ethyl alcohol, and 50 g of potassium hydroxide. The specimens were placed in the clearing solution until clear and the viscera and muscle were soft, about 20–40 min. Then the head and abdomen were disjointed from the thorax. Seventy percent alcohol was jetted into the head, thorax, and abdomen with a hypodermic syringe to remove the softened contents. The clearing solution was withdrawn, and the cleared material washed twice with distilled water. Then the prepared insect material was transferred to glycerine for study. The various structures were illustrated using a projecting microscope.

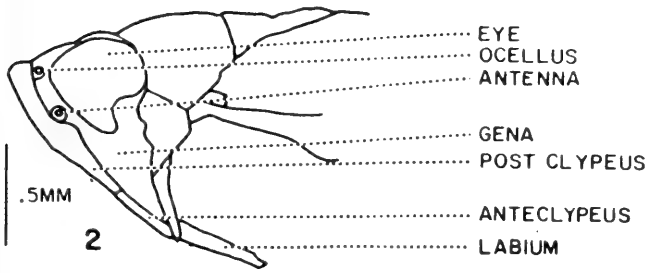
Musculature was studied by dissecting fresh material and examining stained serial sections.

Results and Discussion

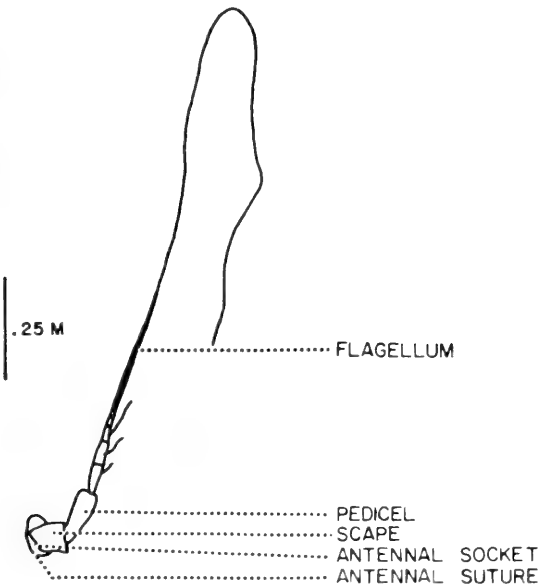
The head in dorsal aspect exhibits the triangular crown and posterolateral compound eyes (Fig. 1). The crown may be pointed or rather bluntly pointed, and the anterior crown margin in lateral aspect usually is rather sharply angled, but in certain species in the oriental region the anterior margin may be rounded, approaching the condition in the genus *Osbornellus*. In lateral view, the dorsal margin of the head is not completely flat (Fig. 2). A single ocellus is situated on the crown margin near each compound eye. The ocelli may be large (0.16 mm) or small (0.04 mm). A coronal suture originates at the



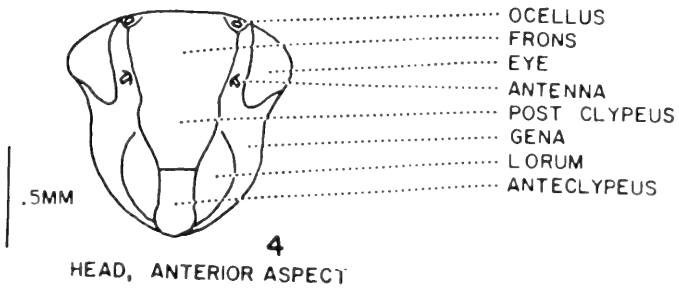
HEAD AND THORAX, DORSAL ASPECT



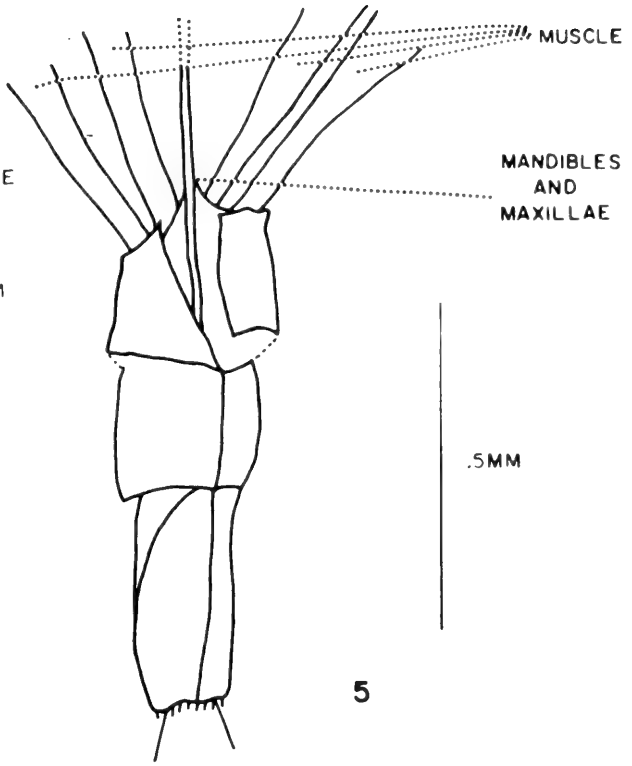
HEAD AND THORAX, LATERAL ASPECT



ANTENNA, DORSAL ASPECT



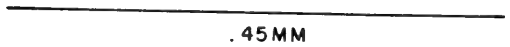
HEAD, ANTERIOR ASPECT



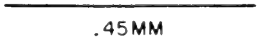
LABIUM, VENTRAL-LATERAL ASPECT

LEFT MANDIBLE, LATERAL ASPECT

TIP OF MANDIBLE, LATERAL ASPECT



MAXILLA, LATERAL ASPECT

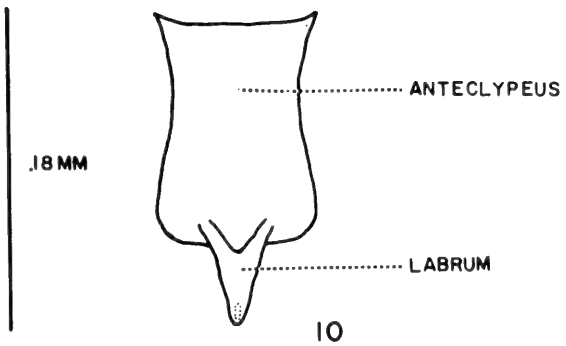


APEX OF MAXILLA

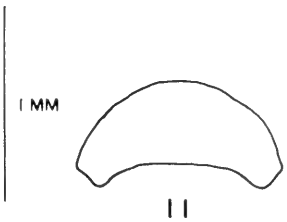
FIGS. 1–9. General morphology of *Scaphoideus* (*Scaphoideus*) *titanus*. 1. Head and thorax, dorsal aspect. 2. Head and thorax, lateral aspect. 3. Antenna, dorsal aspect. 4. Head, anterior aspect. 5. Labium, ventrolateral aspect. 6. Left mandible, lateral aspect. 7. Apex of mandible, lateral aspect. 8. Maxilla, lateral aspect. 9. Apex of maxilla.

posterior center of the crown and extends about half the distance to the anterior margin where it divides and each arm turns laterally. The antennae are setaceous and long (Fig. 3). The scape is cup shaped and frequently ornamented with scale-like sculpturing (Fig. 3). A single seta is present on the first, second, and third flagellar segments. Sensory structures as noted by Hansen (1890) were not found. The face is composed of a median frontal area, clypeal regions, and lateral to the clypeal regions, the "lorea" and genae (Fig. 4). The postclypeus is separated from the anteclypeus by a "transclypeal suture," a segment of the epistomal suture. The epistomal suture originates at the anterior tentorial pits and delineates the lorae, joins the anteclypeal sutures laterally near the ventral portion of the anteclypeus, and proceeds dorsally to the "transclypeal suture." In contrast, Kramer (1950) illustrated *Aulacizes irrorata* and showed the epistomal suture as originating at the frontal sutures. However, the lorae have been variously interpreted. Evans (1946a, 1946b) and Kramer (1950) interpreted the lorae as parts of the clypeus; later Evans (1957) called them paraclypeal lobes. Snodgrass (1938, 1944) and Butt (1943) interpreted the lorae as a part of the hypopharynx. But Pesson (1951), using nerve innervation and embryological evidence, refuted that association. Arora and Singh (1962) stated that the lorae were composite plates formed by the fusion of clypeal, tritocerebral, and mandibular parts. In the genus *Scaphoideus*, the lorae are continuous with the genae. The frontal sutures extend dorsally from the lateral margins of the transclypeal suture to near the antennal sockets where they become somewhat indistinct. They appear to pass the antennae medially and continue to the ocelli where they divide and pass on either side of each ocellus becoming indistinct after passing over the anterior crown margin. Hence, the crown appears to be composed of portions of the frons and vertex. The most lateral areas of the face are the genae. Cogan (1916) indicated that the area was an amalgamation of genae and maxillary plate. However, no exact demarkation is visible anteriorly. The anterior tentorial pits are low on the face. The epistomal suture on leaving the anterior tentorial pit dips nearly to the ventral margin before joining the frontal suture, suggesting that most if not all lateral portions of the face are genae. DuPorte (1962) illustrated the genae as being shortened as the tentorial pit and genital suture of the *Cicada* rose. However, in *Scaphoideus* it seems to be lowered, considerably elongating the genae. The proximal portion of the maxillary stylets are associated with the maxillary lever, the anterior tentorial pits, and hypopharyngeal wings, and not with the lateral portions of the face. Hence, those areas are designated genae. The maxillary stylet has 2 protractor muscles (Arora and Singh 1962) inserted at the ventral margin of the face and immediately adjacent to the anteclypeus. There is no demarkation between genae and maxillary plate on the face, but certainly the maxillary plate is reduced and restricted to a small area ventrally, if present at all anteriorly. Posteriorly, a median suture divides the upper genal portion from what may be the maxillary plate ventrally. Pits on the genae are represented internally by tube- or saclike structures of unknown function. Those saclike structures are heavily sclerotized and appear to bridge the anterior and posterior surfaces. The labium consists of 4 segments, the most apical of which bears several distal setae (Fig. 5). The mandibles (bristles or stylets) are extremely long, thin, laterally flattened, and expanded proximally (Fig. 6). The distal tenth is dentate (Fig. 7). The maxillae are similar to the mandibles but are hooked distally (Figs. 8, 9). The labrum is triangular and reduced (Fig. 10). Cogan (1916) referred to that structure as the epipharynx. However, the epipharynx probably is very reduced and coalesced to the posterior region of the labrum.

The pronotum is sublunate in dorsal view (Fig. 11). Laterally, the episternum is undivided (Fig. 12). The prosternum is

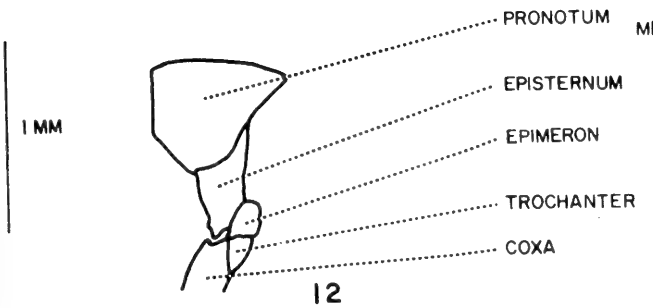


LABRUM AND ANTECLYPEUS

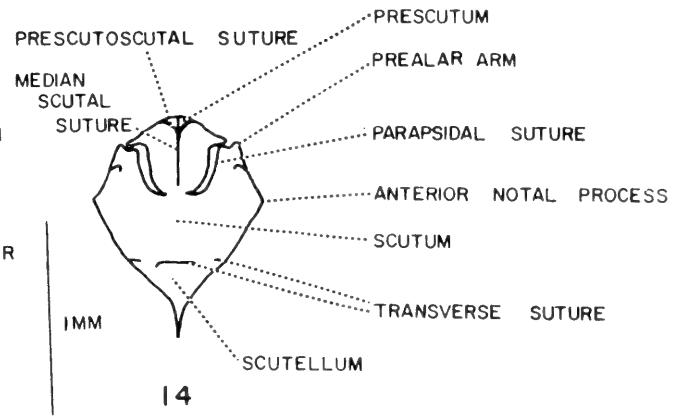


NOTUM, FIRST THORACIC SEGMENT, DORSAL ASPECT

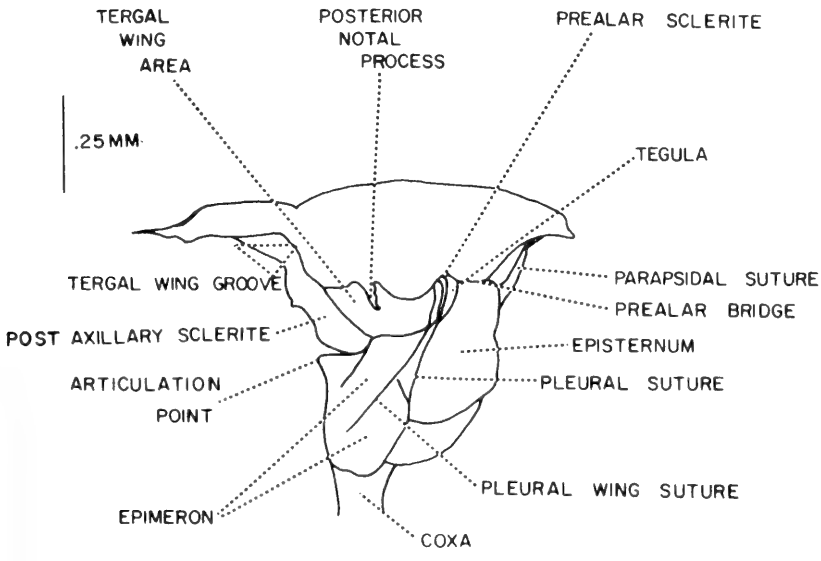
STERNUM, FIRST THORACIC SEGMENT, VENTRAL ASPECT



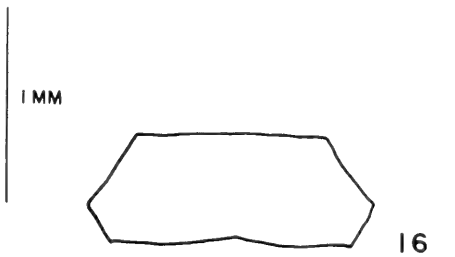
RIGHT PLEURON, FIRST THORACIC SEGMENT, LATERAL ASPECT



NOTUM, SECOND THORACIC SEGMENT, DORSAL ASPECT

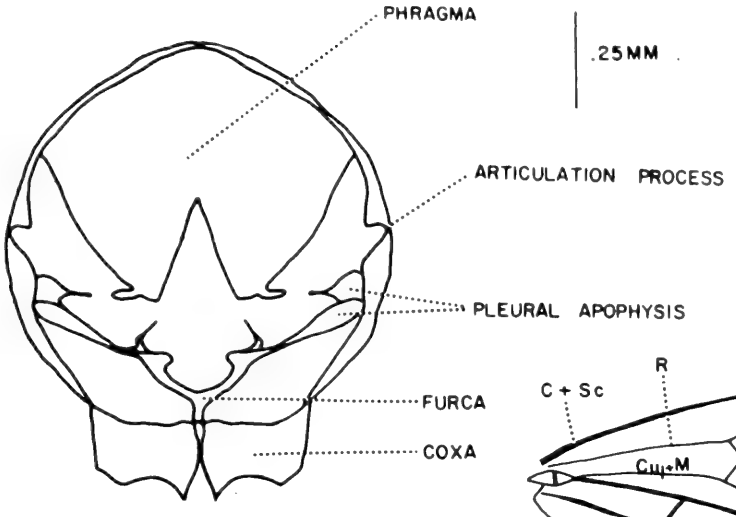


RIGHT PLEURON, SECOND THORACIC SEGMENT, LATERAL ASPECT



STERNUM, SECOND THORACIC SEGMENT, VENTRAL ASPECT

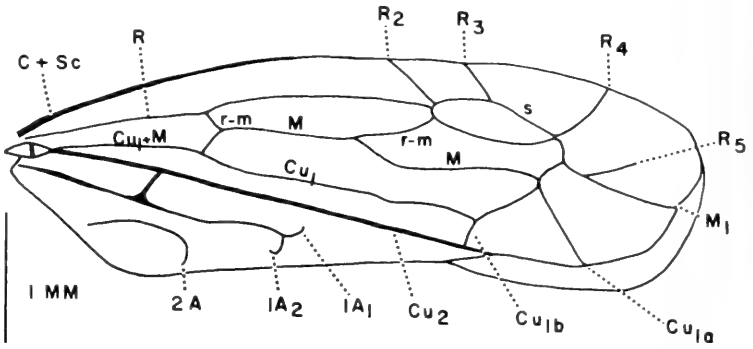
FIGS. 10–16. External morphology of *Scaphoideus* (*Scaphoideus*) *titanus*. 10. Labrum and anteclypeus, dorsal aspect. 11. Notum, first thoracic segment, dorsal aspect. 12. Right pleuron, first thoracic segment, lateral aspect. 13. Sternum, first thoracic segment, ventral aspect. 14. Notum, second thoracic segment, dorsal aspect. 15. Right pleuron, second thoracic segment, lateral aspect. 16. Sternum, second thoracic segment, ventral aspect.



17

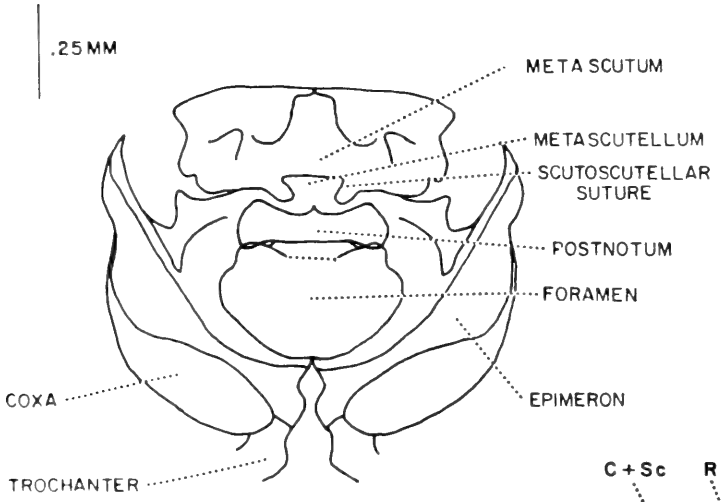
SECOND THORACIC SEGMENT,

POSTERIOR ASPECT



FRONT WING

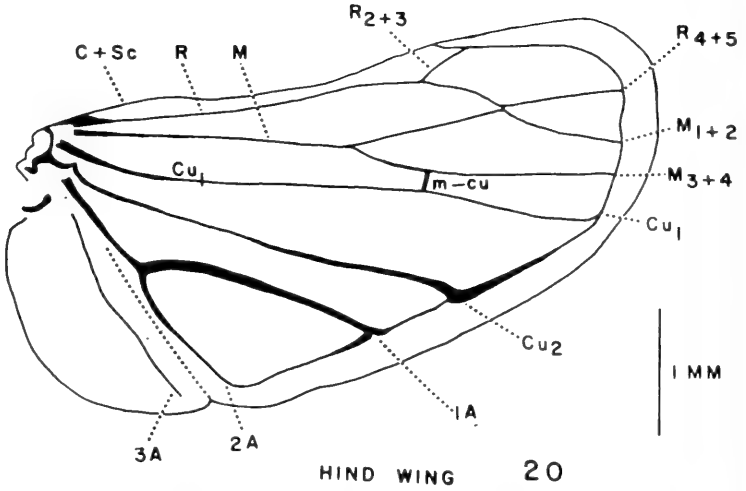
19



18

NOTUM AND PLEURON, THIRD THORACIC SEGMENT,

DORSO-POSTERIOR VIEW



HIND WING 20

FIGS. 17–20. External morphology of *Scaphoideus* (*Scaphoideus*) *titanus*. 17. Second thoracic segment, posterior aspect. 18. Notum and pleuron, third thoracic segment, dorsoposterior aspect. 19. Front wing. 20. Hind wing.

deeply excavated anteriorly and much reduced (Fig. 13). The shape of the prosternum varies considerably in cicadellid genera and is triangular in *Idioscopus clypealis* (Srivastava 1958).

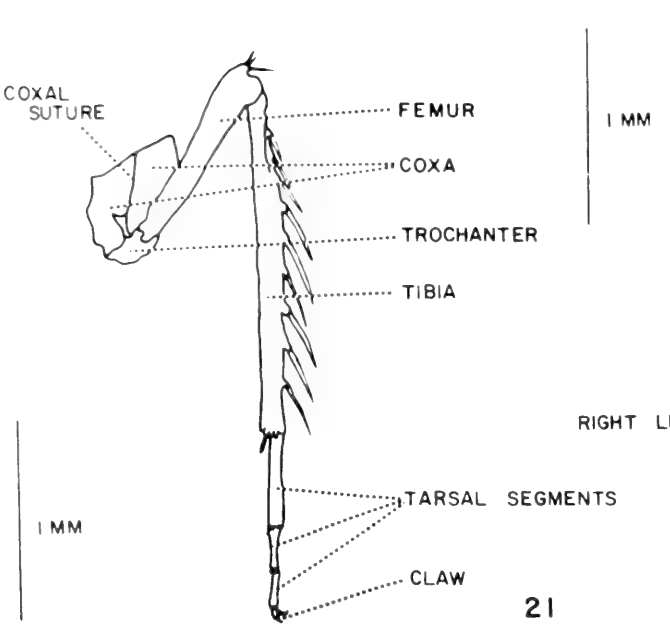
The mesonotum is dorsally rhomboid and incised anterolaterally by the parapsidal suture (Fig. 14). The prescutoscutal suture is anterior to the parapsidal suture and completely separated from it, a condition known to occur in the genus *Aulacizes* (Matsuda 1970). A central median scutal suture originates anteriorly and extends about one-third of the distance to the posterior apex. The transverse suture separates the scutum from the scutellum. A depressed lateral extension of the scutellum forms the tergal wing groove.

The mesothoracic segment in lateral view exhibits the dorsal outline as 2 convex areas (Fig. 15). The episternum is about as large as the epimeron and is more dorsal. The tegula is nearly the same size and form as the prealar sclerite and both are long thin sclerites that are oriented vertically. The mesosternum is 3 times the size of the prosternum and is somewhat rectangular with the lateral margins projected to points (Fig. 16). Internally, the mesothorax is incised dorsally by the phragma which occupies about half of the cavity (Fig. 17). The dorsal pleural apophysis nearly joins a lateral extension of the phragma. The ventral pleural apophysis joins the well-developed Y-shaped furca.

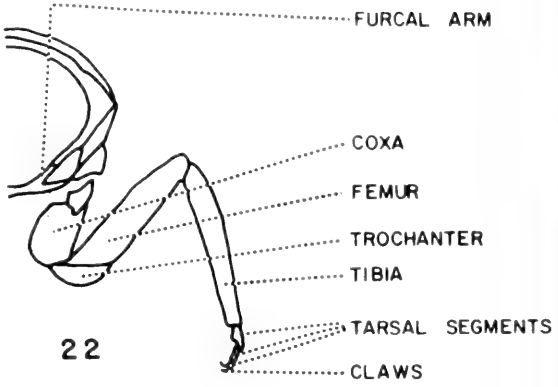
The metathoracic segment is oriented in a nearly vertical plane and is best seen in caudal aspect (Fig. 18). The metascutum and postnotum are subrectangular. Many areas of the metathoracic segment become membranous and are difficult to distinguish. The metascutum usually has 2 caudoventral processes. The pleural sclerites are much narrowed and somewhat indistinguishably fused to each other and to the metanotal sclerites.

The venation of the mesothoracic wing (Fig. 19) and metathoracic wing (Fig. 20) are relatively similar for all species in the genus. In the mesothoracic wing, the costa and subcosta are fused and have transverse ridges on the distal three-fourths. The radius divides in the distal third into R_2, R_3, R_4, and R_5, or R_5 may join M for a short distance before it separates from M. R_5 may or may not reach the wing margin. R_2, R_3, R_4, and R_5 are often termed reflexed veins. The first and second r–m veins are present. The medius separates from Cu_1 in the proximal fourth of the wing and continues unbranched to the wing margin. Cu_1 parallels Cu_2 and divides into Cu_{1a} and Cu_{1b} in the distal fourth of the wing. Cu_{1a} turns anteriorly, closes the distal end of the Cu_1 cell, touches M, and turns sharply to the posterior. Cu_{1b} joins Cu_2 at a right angle. Cu_2 (claval vein or suture) is unbranched. There are 2 anal veins (claval veins of some homopterists); 1A may be branched, but usually neither branch reaches the wing margin. The appendix is well developed. The posterior wing margin is commonly called the commissural vein or line. An earlier terminology existed and is as follows: R before it branches was designated the first sector by some workers, and R was often called the outer branch of the first sector after the juncture of the r–m crossvein. M was called the inner branch first sector after the juncture of the r–m crossvein and the second sector before the juncture of the r–m crossvein. The first R_3 cell was known as the outer anteapical, the first R_5 as the central anteapical cell, and the second M as the inner anteapical cell. Cu_{1a} was known as the first apical cell. The third M cell was called the second anteapical cell. The second R_5 cell was termed the third anteapical cell and the second R_3 cell, the fourth anteapical cell. The Cu_1 cell was sometimes designated the brachial cell.

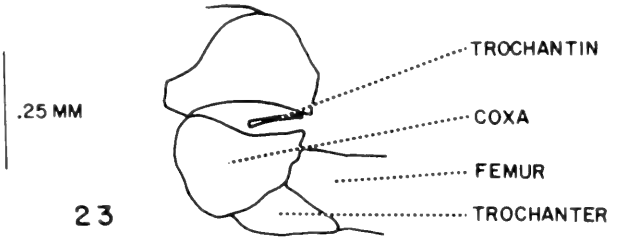
In the metathoracic wing, the costa and subcosta are fused. R branches in the distal third into R_{2+3} which zigzags to the anterior margin and R_{4+5} which proceeds to the wing apex. The medius divides in the midportion of the wing into M_{1+2} and M_{3+4} and both extend to the apex. Cu_1 and Cu_2 are undivided. Cu_2 is considerably enlarged apically. The anal vein is divided medially, and 1A is thickened; 3A is pos-



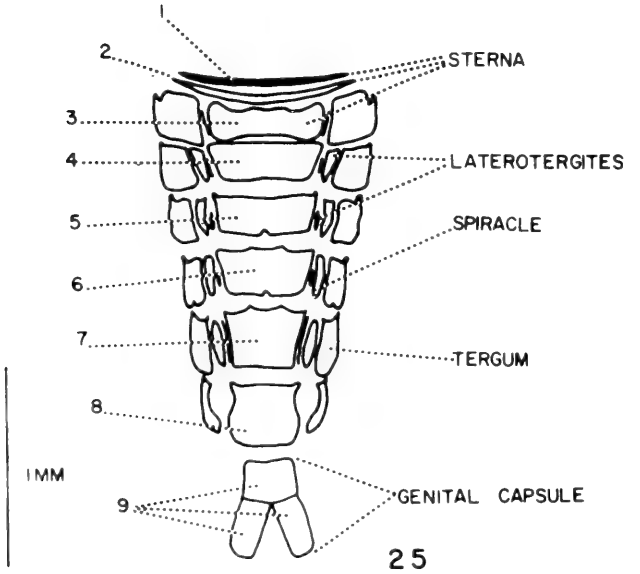
RIGHT LEG OF THIRD THORACIC SEGMENT, VENTRAL ASPECT



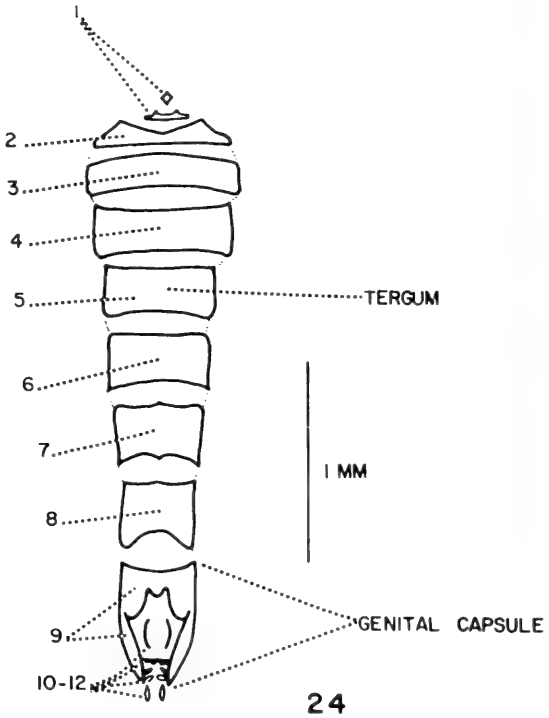
RIGHT LEG, FIRST THORACIC SEGMENT, POSTERIOR ASPECT



RIGHT LEG AND PLEURON, SECOND THORACIC SEGMENT LATERAL ASPECT



MALE ABDOMEN, VENTRAL ASPECT



MALE ABDOMEN, DORSAL ASPECT

FIGS. 21–25. External morphology of *Scaphoideus* (*Scaphoideus*) *titanus*. 21. Right leg of third thoracic segment, ventral aspect. 22. Right leg, first thoracic segment, posterior aspect. 23. Right leg and pleuron, second thoracic segment, lateral aspect. 24. Male abdomen, dorsal aspect. 25. Male abdomen, ventral aspect.

terior to the anal fold, undivided, and does not reach the wing margin.

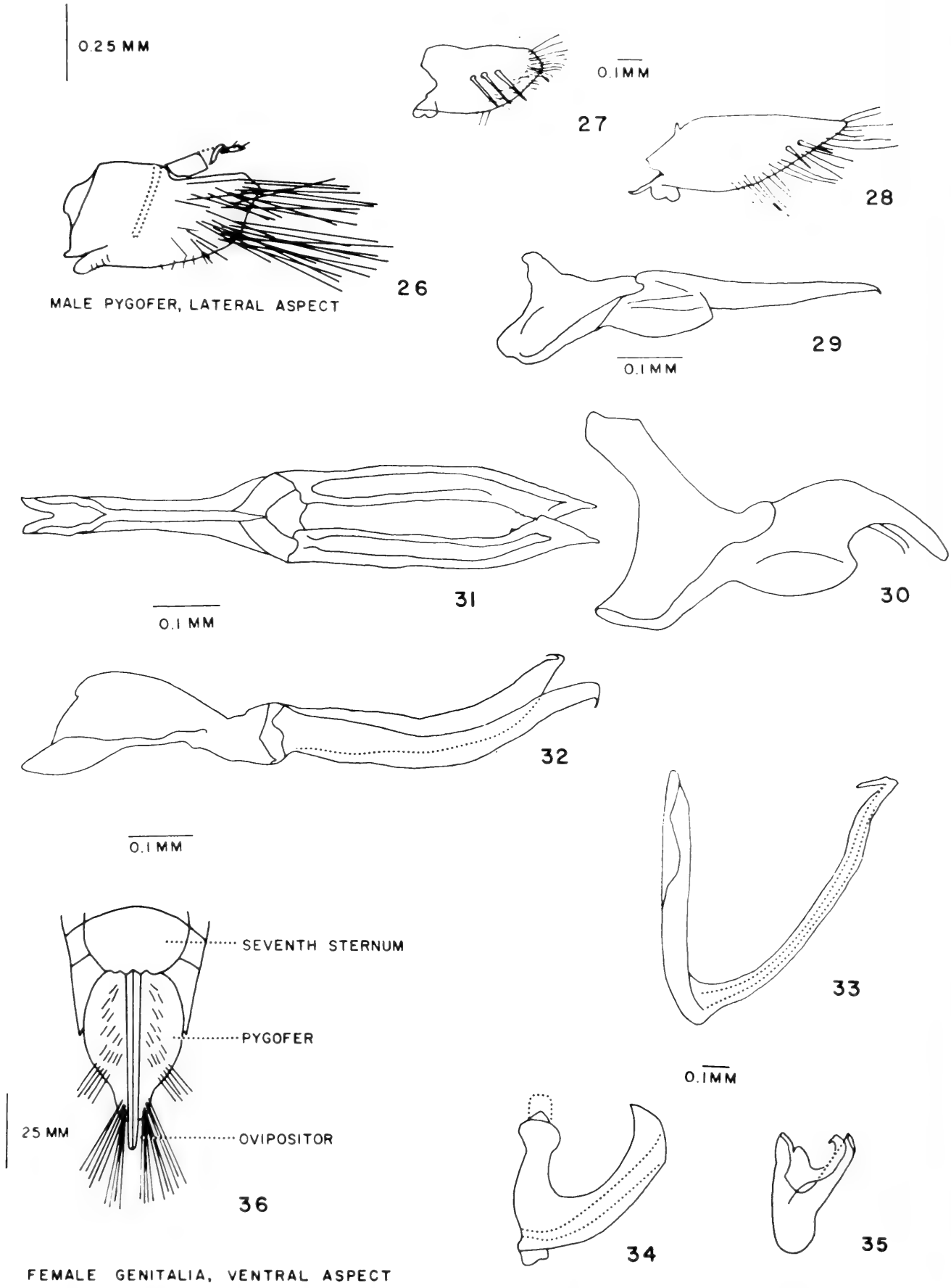
The leg consists of the coxae, trochanter, femur, tibia, 3 tarsal subsegments, pretarsus, pulvillus, and 2 claws (Fig. 21). The procoxae are rather cylindrical, but the mesocoxae and metacoxae are quadrate, and flattened against the ventral body surface (Figs. 22, 23). The trochanter is subtriangular and ventral to the coxae and femur. The hind femur is long with the hind femoral setal formula 2-2-1. The tibia is about twice the length of the femur and has 4 rows of setae, most of which are sculptured. There are platellae at the apex of the tibia and at the apices of the 3 tarsal subsegments. The numbers of platellae are intraspecifically and bilaterally variable. The tarsi may or may not have setae. A short pretarsus is present from which originates apically 2 simple unornamental claws (ungues). A bilobed pulvillus without setae is present.

The abdomen joins the thorax narrowly, then expands immediately and appears broadly joined. The abdomen continues to increase in width and height to a little before the middle, where it decreases in both height and width to the caudal apex. A cross section has a semicircular outline. The terga are arched and form the dorsal and lateral sides; the laterotergites and sterna are flat and form the ventral side of the semicircle. The lateral edges of the terga are bent slightly dorsad before joining the sterna or the laterotergites. The first and second abdominal terga are minute. In dorsal aspect, the first abdominal tergum is divided into 2 pieces, the first diamond shaped (Fig. 24), and the second transversely rectangular with 2 small anterior projections. The second abdominal tergum is a close reproduction of the second piece of the first abdominal tergum. The third abdominal tergum is broadly rectangular and each successive tergum to the eighth is progressively more quadrate except for the female eighth tergum which usually is triangular.

The laterotergites are absent from abdominal segments 1 and 2 (Fig. 25); however, a pair of spiracles is present in the membranous region where they would be situated. The third abdominal segment usually has an undivided laterotergite, but segments 4 through 8 have the laterotergite divided into 2 pieces. The most lateral piece of the laterotergites is the largest and contains the spiracle in the caudal portion. Spiracles are present in laterotergites 4 through 7.

Abdominal sterna 1 and 2 are transversely oriented and extremely long and thin. Sterna 3 through 8 in ventral aspect follow the same form as terga 3 through 8. A cluster of small setae usually is present on the third sternum. The female eighth sternum usually is triangular and fitted into a pocket dorsal to the seventh sternum.

The male genitalia were discovered to be of considerable taxonomic value in the Cicadellidae in the early 1900's. Until that time, little morphological work had been completed on the genitalia of the group and only a few structures had terms assigned to them. Taxonomists adopted the few terms available and/or proposed new terms. Generally, taxonomists did not complete extensive morphological, embryological, or comparative studies. Consequently, homologous terms did not always agree with homologous structures. The confusion was amplified by diverse terms applied to the same structure, or further compounded by designating 2 different structures by the same name. Newell (1918) attempted to clarify the situation for the various orders of insects, and Kershaw and Muir (1922) and Singh-Pruthi (1925) did the same for the auchenorrhynchous Homoptera. Tuxen (1970) listed the various terms applied to genital structures. Considerable controversy existed earlier as to the origin of the genital structures and, consequently, their terminology. Many workers argued that the genital structures were of appendicular origin, others that they were a combination of appendicular and adjacent segmental papillae. Still others believed that genital structures were outgrowths of the sterna. Excellent reviews of the proponents of each



FIGS. 26–36. Morphology of genital structures of several *Scaphoideus* species. 26. Male pygofer, lateral aspect. 27. Right plate, ventral aspect. 28. Right plate, ventral aspect. 29. Right style, ventral aspect. 30. Right style, ventral aspect. 31. Connective and paraphyses, ventral aspect. 32. Connective and paraphysis, lateral aspect. 33. Aedeagus, lateral aspect. 34. Aedeagus, lateral aspect. 35. Aedeagus, lateral aspect. 36. Female genitalia, ventral aspect.

theory and their individual terminologies were given by Nel (1929), Gustafson (1950), Matsuda (1958) and Scharov (1966). However, application of the proper terminology depends upon homology which probably can best be derived and interpreted from comparative morphology as observed during embryology and/or preadult development. Until recently, most terminology inferences were drawn from the study of adult specimens. Smith (1969) suggested that the components of the external genitalia of both sexes of ectognathous insects are homologous in all orders and that the genitalia consist of presumed telopodites or for males perhaps exites of the genital coxopodite. But Helms (1968) determined that the genital structures of *Empoasca fabae* (Homoptera: Cicadellidae) were of sternal origin. He found that primary phallic rudiments in the center of the ninth sternum began to differentiate during the third and fourth stadia into 2 pairs of structures. The lateral structures became the style rudiments, and the median pair of structures became fused on their dorsal and ventral margins to form the aedeagal rudiment. The connective (first phallobase) was not discussed by Helms, but from the position of the rudimentary styles, aedeagus, accessory glands, and ejaculatory duct, it seems reasonable that the connective is of sternal origin, perhaps formed from the rudimentary median mesomeres. The same possibly is true of the paraphyses (= parameres of some authors) which are paired distal structures associated with the connective and aedeagus. Other studies (Kershaw and Muir 1922, Singh-pruthi 1925, George 1928, Metcalf 1932, and Dupis 1949) showed the same kind of development in members of the auchenorrhynchous Homoptera. Studies in most other orders of insects have indicated that the genitalia are of sternal origin (see Matsuda 1958, Smith 1969, and Snodgrass 1963 for references concerning the other orders and the exceptions that exist).

In members of the genus *Scaphoideus*, segments 9 through 12 in the male and 8 through 12 in the female are modified into genital or anal structures. The male external terminalia, commonly called the genital capsule (Fig. 26), are composed of a pygofer formed of 2 large lateral pieces connected by a dorsal bridge, a ventral valve (hypandrium of Crampton 1922), and 2 apical ventral plates (hypovalves) that are mirror images. The lateral walls of the pygofer have a narrow membranous suture from the anterior ventral margin to the middle of the pygofer along an imaginary line from the anterior ventral corner to near the dorsal posterior margin. Setae on the pygofer and plates frequently are sculptured. Spines occur ventrocaudally on the pygofer in some species. The number of setae on structures on the right half of the individual may differ from the left. Frequently, the pygofer apex has 2 tufts of large long setae. The anterior margin of the male plate is membranously attached to the posterior margin of the valve, and the anterolateral apex of the plate is articulated to the lateral apex of the valve. The plates may be bluntly rounded (Fig. 27) or rather sharply pointed (Fig. 28). The valve also is articulated to the pygofer anterolaterally and is obtusely triangular. The male internal genitalia are partially enclosed by the pygofer, valves, and paired plates, and are composed of the paired styles, paraphyses, anal collar, a connective, and an aedeagus. The anal collar may be broad or narrow and is situated in the caudal membrane of the pygofer. The anal collar extends from near the dorsal margin to a little below the middle of the pygofer. The connective is almost entirely internal. The styles are anteriorly internal and caudally external. The aedeagus is external. The styles may be long and attenuated or short and bluntly pointed and broad or narrow at the base (Figs. 29, 30). Setae are present on the styles of some species. The connective is always bifid anteriorly and may be bifid posteriorly. In species that have the connective fused to the paraphyses, the bifid nature of the connective is often indistinguishable (Fig. 31). Dorsal apodemes usually are present on the

connective and sometimes are greatly extended (Fig. 32). The connective is a sclerotized shaft articulated with the styles anterolaterally and fused or articulated posteriorly with the paraphyses. The paraphyses may be small and membranous or large, well sclerotized, and heavily tanned (Fig. 31). They are almost entirely external. The paraphyses are the most specifically unique structures in the genus and take numerous forms distinct for each species. The aedeagus is free and attached only membranously to the connective. The caudal apex of the aedeagus usually is expanded laterally sometimes into spine-like processes. The aedeagal shaft may be long and narrow or short and enlarged (Figs. 33, 34). The dorsal apodeme (paired or double paired) and the preatrium may be pronounced or reduced. A few species have atrial rim processes (Fig. 35). The gonopore is apical on the aedeagus. There appears to be no endotheca or endophallus in species of this genus.

The female external genitalia include segments 8 and 9 (Fig. 36). Segment 8 consists only of a cone-shaped tergum commonly called the pygofer. The ovipositor is fitted into a small narrow ventrocaudal slit in the pygofer. The pygofer tapers to a caudal apex with only the ovipositor in its circular form. The ovipositor is approximately the same width over its entire length and narrows only at the apex.

The ovipositor consists of 3 pairs of valvulae numbered I, II, and III. Valvulae II are innermost and are fused to the valvifer attached to the anterior ventral pygofer. Valvulae I surround Valvulae II in lock-and-key fashion and form the cylindrical tubelike ovipositor sheaths. Valvulae I are membranously attached to the eighth sternum. No valvifer is distinguishable. Valvulae III are much broader than Valvulae I or II and usually bear a group of minute setae on the caudal fifth. Valvulae III are attached to the posterior of the triangular valvifer which is articulated medially to the pygofer and anterolaterally to Valvulae II. The apical two-fifths of Valvulae II are slightly enlarged and bear dorsally a number of teeth near the apex. A single isolated tooth is near the middle. In most species, internal ducts are visible in the caudal portion. The rami of Valvulae I and II are curled dorsally. The ovipositor usually extends beyond the pygofer.

The anal tube is composed of 3 segments, 10, 11, or 12 in both sexes near the dorsal apex of the pygofer. The tenth segment is tubular, and may or may not be divided dorsally. The eleventh segment usually is divided into an anterior and posterior section. The posterior section consists of 2 pairs of oval pieces laterally. The twelfth segment (the telson or anal papilla of Britton 1923 or anopapilla of Crampton 1922) is elongate and is called the flicker by some homopterists. It bears the anal opening or anolabii as a dorsal slit. Usually, the anal slit is flanked laterally by small setae and bears several long setae apically.

LITERATURE CITED

ARORA, G. L., AND S. SINGH. 1962. Morphology and musculature of the head and mouth parts of *Idiocerus atkinsoni* Leth. (Jassidae, Homoptera). J. Morph. 110:131–140.

BRITTON, W. H. 1923. Papers on the leafhoppers (Cicadellidae) of Nova Scotia. Proc. Acadian Entomol. Soc. 1922:57–72.

BUTT, F. H. 1943. Comparative study of mouth parts of representative Hemiptera-Homoptera. Cornell Univ. Agr. Exp. Sta. Mem. 254:3–20.

COGAN, E. S. 1916. Morphological studies of the superfamily Jassoidea. Ohio J. Sci. 16:299–325.

CRAMPTON, G. C. 1922. The genitalia of the males of certain Hemiptera (Heteroptera) and Homoptera. Bull. Brooklyn Entomol. Soc. 17(2):46–65.

DELONG, D. M. 1926. A monographic study of the North American species of the genus *Deltocephalus*. Ohio St. Univ. Univ. Studies Contr. Zool. Entomol. 2(13):1–129.

DUPIS, C. 1949. Contribution à l'etude morphologique des Homoptera. Stades préimaginaux de *Ledra aurita* (L.). Remarques sur le developpement des organes genitaux externes. Can. Nat. 4:43–47.

DUPORTE, E. M. 1962. The anterior tentorial arms in insects and their significance in interpreting the morphology of the cranium of the cicadas. Can. J. Zool. 40:137–144.

EVANS, J. W. 1946a. A natural classification of leafhoppers (Jassoidea, Homoptera). Trans. Roy. Entomol. Soc. Lond. 96(3):47–60.

———. 1946b. A natural classification of leafhoppers (Homoptera, Jassoidea) Part 2: Aetalionidae, Hylicidae, Eurymelidae. Trans. Roy. Entomol. Soc. Lond. 97(2):39–54.

———. 1957. Some aspects of the morphology and interrelationships of extinct and recent Homoptera. Trans. Roy. Entomol. Soc. Lond. 109(9):17–294.

GEORGE, C. J. 1928. The morphology and development of the genitalia and genital ducts of Homoptera and Zygoptera shown in the life histories of *Philaenus* and *Agrion*. Quart. J. Microsc. Sci. 72:447–485.

GUSTAFSON, J. F. 1950. The origin and evolution of the genitalia of the insects. Microentomology 15(2):35–67.

HANSEN, H. J. 1890. On the morphology and classification of the auchenorrhynchous Homoptera. Transl. by G. W. Kirkaldy. 1900–1903 Entomologist. 33:116–120, 169–172, 334–337; 34:149–154; 35:214–217, 234–236, 260–263; 36:42–44, 64–67, 93–94.

HELMS, T. J. 1968. Postembryonic reproductive systems development in *Empoasca fabae*. Ann. Entomol. Soc. Amer. 61(2):316–332.

KERSHAW, J. C., AND F. MUIR. 1922. The genitalia of the auchenorrhynchous Homoptera. Ann. Entomol. Soc. Amer. 15:201–212.

KRAMER, S. 1950. Morphology and phylogeny of the auchenorrhynchous Homoptera (Insecta). III. Biol. Monogr. 20(4):1–111.

MATSUDA, R. 1958. On the origin of the external genitalia of insects. Ann. Entomol. Soc. Amer. 51:84–94.

———. 1970. The insect thorax. Mem. Entomol. Soc. Can. 76:1–431.

METCALF, Z. P. 1932. Notes on the structure and development of the reproductive organs in *Philaenus spumarius* L. Quart. J. Microsc. Sci. 75:467–481.

NEL, R. 1929. Studies of the development of the genitalia and genital ducts in insects. I. Female of Orthoptera and Dermaptera. Quart. J. Microsc. Sci. 73:25–85.

NEWELL, A. G. 1918. A comparative morphology of the genitalia of insects. Ann. Entomol. Soc. Amer. 11(2):109–142.

OMAN, P. W. 1949. The nearctic leafhoppers (Homoptera: Cicadellidae). A generic classification and check list. Wash. Entomol. Soc. Mem. 3:1–253.

ORIAN, A. J. E. 1964. Morphology of the male genitalia of *Abricta ferruginosa* (Stal). Proc. Roy. Entomol. Soc. Lond. (A) 39(1–3):1–4.

PESSON, P. 1951. Ordre des Homopteres. *In* P. Grasse. Traite de Zoologie. 10(2):1390–1656.

SCHAROV, A. G. 1966. Basic Arthropodan Stock. Pergamon Press, Oxford, Eng. 271 pp.

SINGH-PRUTHI, H. 1925. The morphology of the male genitalia in Rhynchota. Trans. Roy. Entomol. Soc. Lond. 1925:127–267.

SMITH, E. L. 1969. Evolutionary morphology of external insect genitalia, I. Origin and relationships to other appendages. Ann. Entomol. Soc. Amer. 62(5):1051–1078.

SNODGRASS, R. E. 1938. The loral plates and the hypopharynx of Hemiptera. Proc. Entomol. Soc. Wash. 40:228–236.

———. 1944. Feeding apparatus of biting and sucking insects affecting man and animals. Smithson. Misc. Coll. 104(7):1–113.

———. 1963. A contribution toward an encyclopedia of insect anatomy. Smithson. Misc. Coll. 146(2):1–146.

SRIVASTAVA, B. K. 1958. On the external morphology of *Idiocerus clypealis* Leth. (Homoptera: Jassidae). Beit. Entomol. 8(5/6):732–744.

TUXEN, S. L. 1970. Taxonomists' glossary of genitalia. 2nd. Ed. J. Jorgensen and Co. Munksgaard, Copenhagen, Denmark. 359 pp.

Reactivity of Treated and Untreated Marble in Carbon Dioxide Atmospheres

K. L. Gauri, Preeyaporn Tanjaruphan, Madiraju Appa Rao, and Thornton Lipscomb
University of Louisville, Louisville, Kentucky 40208

Abstract

Marble specimens were impregnated with certain epoxies and fluorocarbon–acrylic copolymers. The treated and untreated specimens were exposed to, while immersed in deionized water, 0.983, 6.2, 8.28, and 11.02 percent pCO_2 at 20 C in a dynamic system. The concentration of leached Ca^{2+} in the water was determined by EDTA titrations and atomic absorption. The values obtained by those methods were nearly identical. The rate of reaction was based on the increment in Ca^{2+} concentration as a function of time. The equilibrium constant K, calculated from the experimental data, had a value of 1.49×10^{-6}, and compared well with the value of 1.58×10^{-6} given by Garrels and McKenzie (1971). Specimens treated with fluorocarbon–acrylic compounds revealed only one-half reactivity relative to untreated specimens in the initial phases of reaction. Certain epoxies provided protection, other epoxies actually enhanced the rate of reaction. It is proposed that pertinent data generated in the course of this study be used as a basis for quantitative performance criteria for stone and concrete preservative treatments.

Introduction

Carbon dioxide is a prominent agent of stone decay. When dissolved in water, carbon dioxide (CO_2) generates hydrogen (H^+) ions that are responsible for dissociation of calcareous and silicate minerals, essential ingredients of most building stones.

The equilibrium concentration of CO_2 in water is a function of temperature and its partial pressure in the atmosphere. The past 100 years have witnessed an increment of 13 percent in the CO_2 budget of the atmosphere due to an increase in the combustion of fossil fuels (Bolin and Erickson 1959). That situation has necessitated development of preservative materials and methods for building stones. But, while such materials and methods have multiplied, the development of criteria for their performance has lagged behind seriously. One of the purposes of this paper is to present means to preservation technologists for a rapid laboratory evaluation of proposed preservative treatment against CO_2 attack. Another purpose of this paper is to show that careful laboratory testing of preservative materials is necessary to determine whether a given material will provide protection since it is likely that certain so-called preservatives may enhance the reactivity.

In our continuing studies since 1970 on deterioration and preservation of stone, we have reported earlier on sulfur dioxide–calcite reactivity (Gauri et al. 1973, Gauri and Sarma 1973), on the usefulness of certain industrial resins as stone preservatives (Gauri 1974b, Gauri et al. 1973, 1974), on a technique for in-depth impregnation (Gauri 1970, U. S. Patent 1974), and on comparative physical properties of certain treated and untreated calcareous stones (Gauri 1974a, Gauri et al. 1974). This supplements our earlier studies, and has yielded data for determining the equilibrium constant of CO_2–$CaCO_3$ reactions. Inferences have been drawn from this study to show that the initial reaction rate rather than the equilibrium concentration is useful in predicting the CO_2–$CaCO_3$ reactivity in the ambient.

Acknowledgments

We thank Dr. Louis A. Krumholz, Director of the Water Resources Laboratory, University of Louisville, and the Air Pollution Control Board, Jefferson County, for

the use of their Atomic Absorption Spectrometers.

Materials

The test samples were rectangular blocks, $4.5 \times 3.2 \times 0.5$ cm, cut from Alabama white and Vermont green marbles. Those marble species were selected because of their higher reactivity with chemically active gases. The final grinding finish on the blocks was obtained with 400-grit silicon carbide powder. The specimens were cleaned ultrasonically; the control was cleaned before exposure to concentrated atmosphere, and other specimens were cleaned before treatment.

Treatment

The experimental specimens were treated with epoxies such as aliphatic diepoxides and bisphenol-A diglycidal ether. Fluorocarbons and acrylics also were used for treatment. Treatment varied from surface coatings to in-depth impregnations. While the surface coatings were made by short-term immersion or brushing of polymers, the in-depth impregnations were obtained by sequential immersion of specimens in polymer-solvent mixtures of increasing polymer concentration (Gauri 1970, U. S. Patent 1974). Specifically, the treatments for each kind of marble were:

Specimen A.—Treatment with bisphenol-A epoxy resin: immersion in acetone, 10 min, followed by immersion in 50 percent and 80 percent epoxy solution in acetone, 20 min each.

Specimen B.—Treatment with bisphenol-A epoxy resin: immersion in acetone, 10 min, followed by immersion in 50 percent epoxy solution in acetone, 30 min.

Specimen C.—Treatment with bisphenol-A epoxy resin followed by coating with a fluorocarbon: immersion in acetone, 10 min, followed by immersion in 50 percent epoxy; surface cleaned with acetone; after epoxy polymerization surface coated with 15 percent fluorocarbon in methyl ethyl ketone (MEK).

Specimen D.—Treatment with aliphatic diepoxide: immersion in 50 percent epoxy in acetone, 30 min.

Specimen E.—Control.

Specimen F.—Treatment with aliphatic diepoxide: immersion in absolute epoxy, 20 min.

Specimen G.—Treatment with fluorocarbon–acrylic copolymer: immersion in 2.5 percent resin in 1:1 MEK-cellusolve acetate, 10 min, followed by immersion in 15 percent resin, 10 min.

The bisphenol-A epoxy and the aliphatic diepoxide were obtained from Celanese Speciality Coatings, P.O. Box 857, Louisville, Ky. 40201; the fluorocarbon and the acrylic were obtained from E. I. Dupont de Nemours & Company, Inc., Wilmington, Del. 19898.

Experimental Setup

All specimens, both treated and untreated, were completely immersed in deionized water for a minimum of 24 hours to insure that they did not absorb water when exposed to CO_2 atmosphere in an immersed state. The experimental work was conducted in 2 phases: (1) the Vermont green marble was immersed in 20 ml of water in a 50-ml beaker such that about half of the specimen was immersed while the other half was above water, and (2) the sample of Alabama white marble was completely immersed in 45 ml of water. Then specimens were placed in the reaction chamber (Fig. 1). After a known period of time, as given in respective figures, the beakers were removed and analyzed for Ca^{2+} ion by titrating a known volume of sample with standard EDTA solution using Eriochrome Black T as an indicator. The total Ca^{2+} ion concentration in the case of the half-submerged specimen for a given period of time is lower than that of a fully immersed specimen. The results, however, are comparable within each phase of the work. Magnesium chloride solution was added before the titration for a better resolution of the endpoint. The volume of EDTA required to neutralize the Mg^{2+} ions was subtracted from

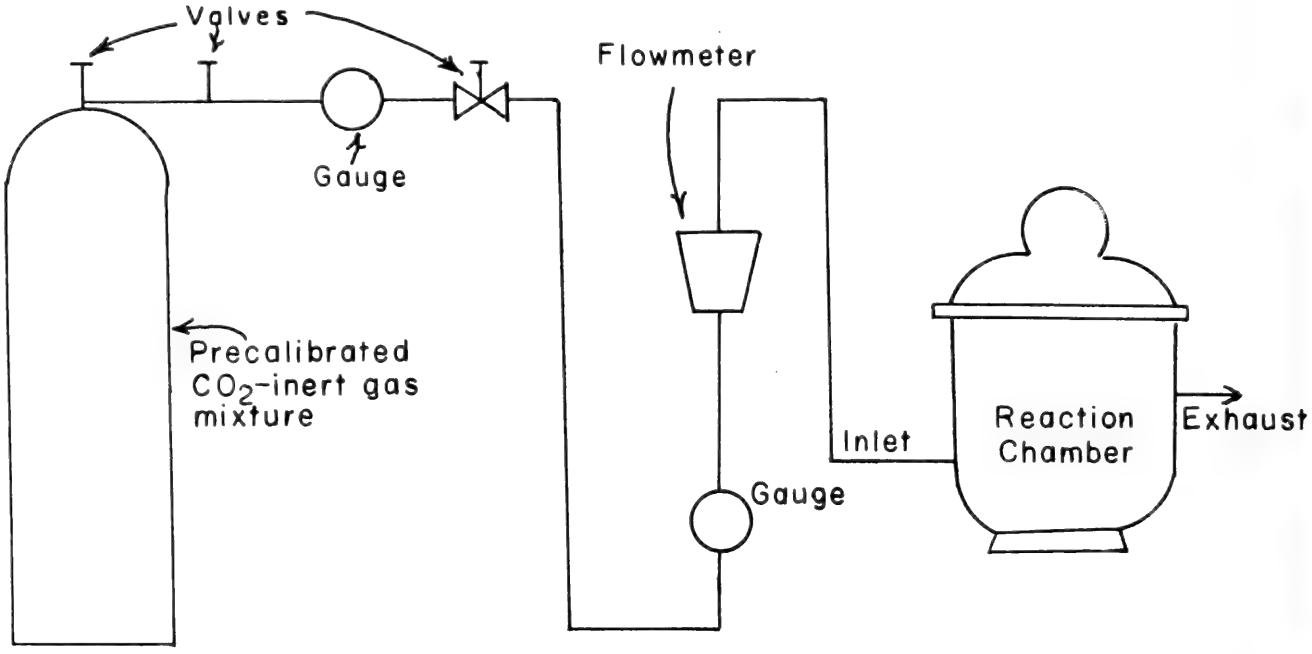


FIG. 1. Schematic detail of dynamic reaction chamber.

the total titer value. The Ca^{2+} ion concentration also was determined by atomic absorption for some runs, and the results obtained by both methods agreed to within 5 percent. The temperature throughout the reaction was maintained at 20 C. The experiment was repeated for various time periods and the concentration of Ca^{2+} ions was plotted as a function of time (Figs. 2–6). The concentration of CO_2 in the cylinder was determined by absorbing CO_2 in ascarite (Hamilton and Simpson 1952: 351). The cylinders with known CO_2 concentration in air or nitrogen were provided by Air Products and Chemicals Inc., 733 West Broad Street, Emmaus, Pa. 18049, who determined the CO_2 concentration by gas chromatography. The CO_2 concentration was checked both at the entrance of the gas in the reaction chamber as well as at the exit by the standard method of reacting the gas with ascarite. A fairly small concentrational difference between the gas at the entrance and the exit was maintained by exposing only a small number of specimens in the reaction chamber.

REACTION KINETICS

Extensive studies have been conducted on the calcium carbonate–carbon dioxide–water reactions. The study by Miller (1952), though conducted for the geological implications of this reaction, is outstanding for several reasons; it includes a comprehensive literature survey on the subject, and it contains experimental work on 3 different sources of $CaCO_3$ with distilled water, NaCl solution, and sea water used as solvent. It also contains data on $CaCO_3$ solubility as a function of temperature and CO_2 pressure.

Some of the reactions taking place in the $CaCO_3$–CO_2–H_2O system could be written as:

$$H_2O + CO_2 = H_2CO_3 \quad (1)$$

$$H_2CO_3 = H^+ + HCO_3^- \quad (2)$$

$$HCO_3 = H^+ + CO_3^{2-} \quad (3)$$

$$CaCO_3 + H^+ = Ca^{2+} + HCO_3^- \quad (4)$$

Hougen et al. (1959:1062–1069) considered several other possible reactions and plotted the concentration of Ca^{2+}, HCO_3^-, CO_3^{2-}, H^+, OH^-, and $H_2CO_3(aq)$ as a function of the partial pressure of CO_2. They concluded that at CO_2 pressures above 10^{-4} atmospheres the concentrations of (OH^-), (CO_3^{2-}), and (H^+) were negligible in comparison to the Ca^{2+}, HCO_3, and H_2CO_3. In that range, they proposed that

the reaction takes place according to the stoichiometric equation:

$$CaCO_3\,(s) + H_2O\,(l) + CO_2\,(g) = Ca^{2+} + 2HCO_3^- \quad (5)$$

This equation could also be obtained by combining Equations 1, 2, and 4. Equation 3 was neglected since there was no detectable trace of CO_3^{2-} as ascertained by titrating with HCl using the double indicator method.

The equilibrium constant for Equation 5 may be written as:

$$K = \frac{(aCa^{2+})\,(aHCO_3^-)^2}{(aCO_2\,(g))} \quad (6)$$

Since this deals with very dilute solutions, the activities can be replaced by the respective concentrations. Also by replacing aCO^2 by the partial pressure of CO_2 the equation can be written:

$$K = \frac{(Ca^{2+})\,(HCO_3^-)^2}{pCO_2} \quad (7)$$

From the stoichiometry of the equation we have $2(Ca^{2+}) = (HCO_3^-)$. Hence, Equation 7 becomes:

$$K = \frac{4(Ca^{2+})^3}{pCO_2} \quad (8)$$

As shown in Fig. 2, the Ca^{2+} concentration increased with time, asymptotically reaching the equilibrium value. That equilibrium value of Ca^{2+} was substituted in Equation 8 and the value of K was calculated for each CO_2 pressure (Table 1). The average value of equilibrium constant, K, is 1.49×10^{-6}. Garrels and McKenzie (1971) reported a value of 1.58×10^{-6} for reaction at room temperature. Hougen et al. (1959) obtained a value of 0.6×10^{-6} from thermodynamic calculations. They selected the following reactions:

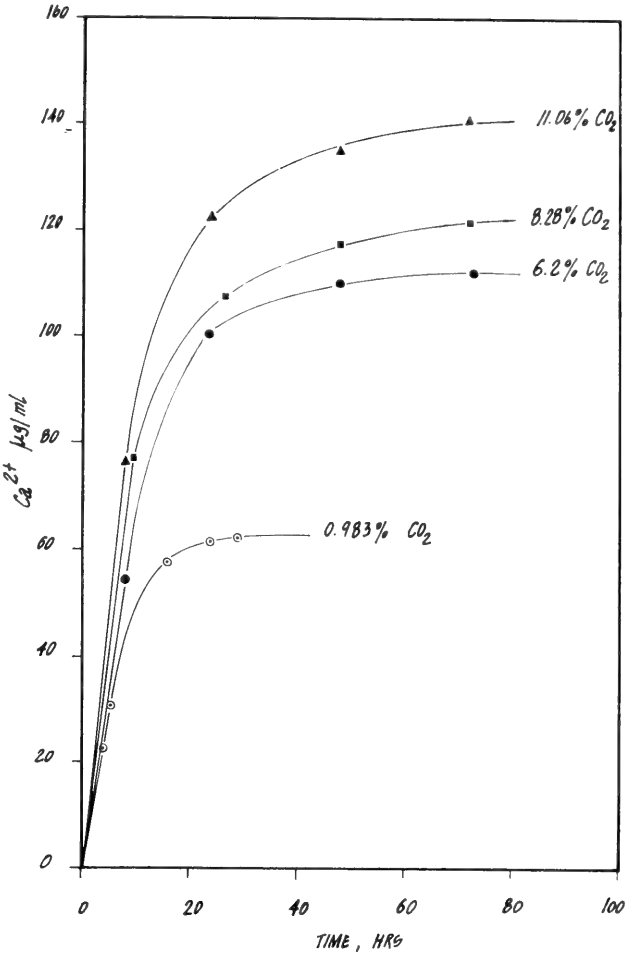


FIG. 2. Reaction rate for untreated Vermont green marble specimens at different CO_2 partial pressures.

$$CaCO_3\,(s) = Ca^{2+} + CO_3^{2-}$$
$$K_1 = 5 \times 10^{-9} = (Ca^{2+})\,(CO_3^{2-})$$

$$H_2O\,(l) = H^+ + OH^-$$
$$K_2 = 10^{-14} = (H^+)\,(OH^-)$$

$$H_2CO_3\,(aq) = H^+ + HCO_3^-$$
$$K_3 = 4.2 \times 10^{-7} = (H^+)\,(HCO_3^-)/H_2CO_3$$

$$H_2CO_3\,(aq) = H_2O + CO_2\,(g)$$
$$K_4 = 29.6 = CO_2\,(g)/H_2CO_3$$

$$HCO_3 = H^+ + CO_3^{2-}$$
$$K_5 = 4.8 \times 10^{-11} = (H^+)\,(CO_3^{2-})/(HCO_3^-)$$

TABLE 1.—REACTIVITY OF CALCITE IN CO_2 ATMOSPHERES OF VARIABLE CONCENTRATIONS

pCO_2	Ca^{2+} µg/ml at equilibrium	$K = \frac{4\,(Ca^{2+})^3}{pCO_2}$
9.83×10^{-3}	62.8	1.57×10^{-6}
6.20×10^{-2}	113	1.45×10^{-6}
8.28×10^{-2}	121	1.34×10^{-6}
11.0×10^{-2}	141	1.59×10^{-6}

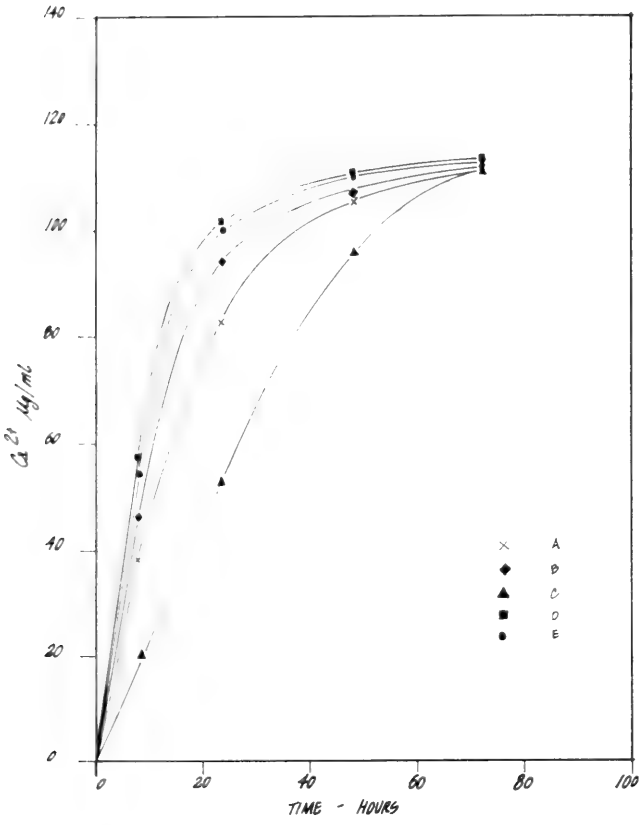


FIG. 3. Effect of different treatment on reaction rate at 6.2 percent CO_2 concentration on Alabama white marble. The treatments were (A) treatment with bisphenol-A epoxy resin: immersion in acetone, 10 min followed by immersion in 50 percent and 80 percent epoxy solution in acetone, 20 min each; (B) treatment with bisphenol-A epoxy resin: immersion in acetone, 10 min, followed by immersion in 50 percent epoxy solution in acetone, 30 min; (C) treatment with bisphenol-A epoxy resin followed by coating with a fluorocarbon: immersion in acetone, 10 min, followed by immersion in 50 percent epoxy; surface cleaned with acetone; after epoxy polymerization surface coated with 15 percent fluorocarbon in methyl ethyl ketone; (D) treatment with aliphatic diepoxide: immersion in 50 percent epoxy in acetone, 30 min; (E) control.

Combining Equation 7 with the above equations yields:

$$K = \frac{(Ca^{2+})\,(HCO_3^-)^2}{CO_2\,(g)} = \frac{K_1K_3}{K_4K_5} = 1.48 \times 10^{-6}$$

This value compares favorably with the experimental value of 1.49×10^{-6}. More recent values for carbonate equilibria calculations given by Thrailkill (1976, Table 1) yield a value of 1.6×10^{-6}.

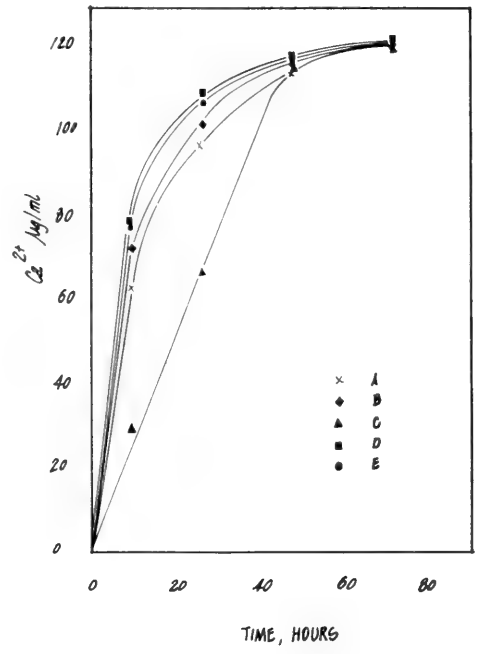


FIG. 4. Effect of different treatments at 8.28 percent CO_2 concentration on Alabama white marble. The treatments were the same as in Fig. 3.

RESULTS AND DISCUSSION

This study has produced the following significant results:

1. Treatment with certain polymers, e.g., bisphenol A type epoxies, acrylics, and fluorocarbons provided protection to the marble blocks, but the treatment with aliphatic diepoxide increased CO_2–$CaCO_3$ reactivity in the earlier runs of reactions.

The increased CO_2–$CaCO_3$ reactivity for specimens treated with aliphatic diepoxide is parallel to results previously reported for SO_2–$CaCO_3$ reactivity (Gauri and Sarma 1973). The increased reactivity may be due to absorption of CO_2 by the polymer film, as in the case of SO_2, or due to the polymer film acting as a semipermeable film to CO_2 permeation. We have determined experimentally that the aliphatic diepoxide film does not absorb CO_2. The other likely explanation then is that CO_2 permeates selectively through the polymer film and thus builds a larger concentration at the calcite–polymer interface. The CO_2 concentration outside the film remains constant. This phenomenon, i.e., the concentration of CO_2 at polymer–$CaCO_3$ interface, must have been of a shorter

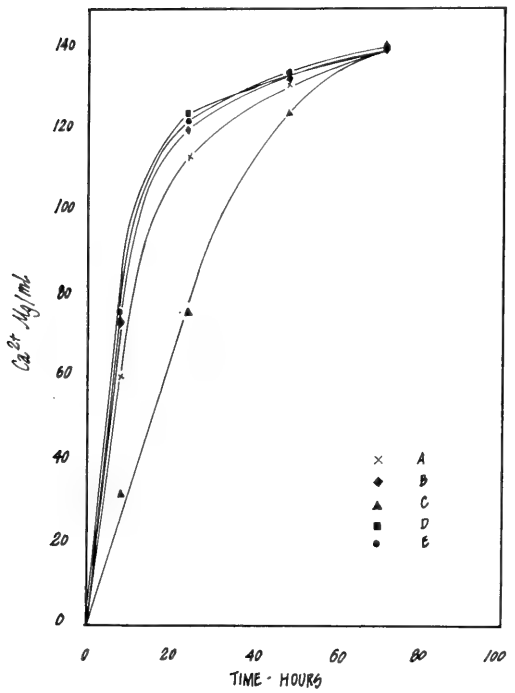


FIG. 5. Effect of different treatments at 11.06 percent CO_2 concentration on Alabama white marble. The treatments were the same as in Fig. 3.

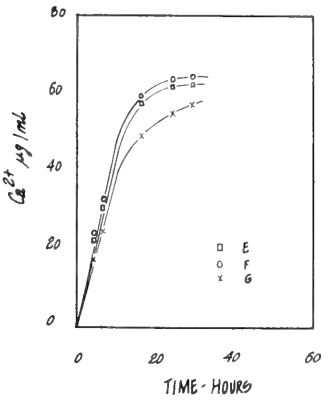


FIG. 6. Effect of different treatments at 0.983 percent CO_2 concentration on Alabama white marble. The treatments were: (E) control (F) treatment with aliphatic diepoxide: immersion in absolute epoxy, 20 min; (G) treatment with fluorocarbon–acrylic copolymer: immersion in 2.5 percent resin in 1:1 MEK-cellusolve acetate, 10 min, followed by immersion in 15 percent resin, 10 min.

duration because the reaction equilibrium of treated and untreated marble occurred at the same level of Ca^{2+} concentration. The reduced initial CO_2–$CaCO_3$ reactivity of other treated specimens probably is due to the reduced rate of water absorption as given in the following section.

2. Marble specimens treated with the same polymer but with in-depth impregnation initially showed lesser reaction than those with shallow impregnation or those with no treatment at all. The phenomenon seems directly related to the rate of water movement into the specimen. The impregnation, by partially causing closure of certain pores and partially by being of water repellent materials, reduces the capillary movement of water into the stone. Yet in the long run, so much calcite is available that the reaction finally reaches equilibrium.

By corollary of the above, considerable protection can be provided to the stone by drastic reduction in the rate of flow of water. In nature, other than upward migration of ground water, the water of consequence for CO_2–$CaCO_3$ reactivity is rainwater. The approximate duration of the reaction is during the showers. The products of reaction do not accumulate. Therefore, with each new shower, the reaction begins anew. The actual CO_2–$CaCO_3$ reactivity in nature thus may be correlated with the initial reaction rate. The treatments, especially in-depth impregnation, therefore are very useful in retarding CO_2–$CaCO_3$ reactivity.

3. The comparisons of reaction rates in the initial phases of reaction may form the basis for performance criteria of treatments for calcareous stone and concrete. For instance, a performance requirement may read as follows: a film deposited on calcareous substrate from 10 percent solids of polymer in solution shall reduce the CO_2–$CaCO_3$ reactivity by at least one-half in the first 5 hours of reaction as compared with a similar untreated specimen exposed in the same environment for the same duration.

LITERATURE CITED

BOLIN, B., AND E. ERICKSON. 1959. Changes in the CO_2 content of the atmosphere and sea due to fossil fuel combustion. Pp. 130–142. *In* B. Bolin (Ed.). The atmosphere and sea in motion. Oxford Univ. Press, London, Eng.

GARRELS, R. M., AND F. T. MCKENZIE. 1971. Evolution of sedimentary rocks. W. W. Norton Co., Inc. New York, N. Y. 397 pp.

GAURI, K. L. 1970. Improved impregnation technique for the preservation of stone statuary. Nature (London) 228:882.

————. 1972. Cleaning and impregnation of marble. Pp. 231–237. *In* Treatment of stone, Centro per la Conservazione delle Sculture All'aperto. Bologna, Italy.

————. 1974a. Decay and its preservation in natural stone. Trans. Ky. Acad. Sci. 35(1–2):29–36.

————. 1974b. Efficiency of epoxy resins as stone preservatives. Stud. Cons. 197:100–101. Amsterdam, Netherlands.

————, M. V. APPA RAO, AND H. J. GADIJAR. 1974. Certain epoxies, silicones, and vinyls as stone preservatives. P. 750. *In* Symposium on preservation of stone. Geol. Soc. Amer. 1974 Ann. Meet. (abs.).

————, G. C. DODERER, N. T. LIPSCOMB, AND A. C. SARMA. Reactivity of treated and untreated marble specimens in an SO_2 atmosphere. Stud. Cons. 18:25–35. Amsterdam, Netherlands.

————, D. J. HAGERTY, AND C. R. ULRICH. 1972. Comparative physical properties of treated and untreated marble. Engin. Geol. 6:235–250.

————, AND A. C. SARMA. 1973. Controlling weathering of marble in a dynamic atmosphere. Pp. 209–223. *In* Third Ann. Environ. Engin. Sci. Conf., Louisville, Ky.

HAMILTON, L. F., AND S. G. SIMPSON. 1952. Quantitative chemical analysis. Tenth Ed. The Macmillan Co., New York, N. Y. 529 pp.

HOUGEN, O. A., K. M. WATSON, AND R. A. RAGATZ. 1959. Chemical process principles (Part 2). John Wiley & Sons, New York, N. Y. 1072 pp.

MILLER, J. P. 1952. A portion of the system calcium–carbon dioxide–water, with geological implication. Amer. J. Sci. 250:161–203.

THRAILKILL, J. 1975. Carbonate equilibria in karst waters. Pp. 745–771. *In* Karst hydrology and water resources. Proc. US–Yugoslav. Symp., Dubrovnik, Yugo.

U. S. PATENT 3,795,533. 1974. Preservation and strengthening of porous solids.

The Fishes of Goose Creek, Jefferson County, Kentucky: A Stream Under the Influence of Urban Development[1]

DAVID S. WHITE[2], FREDERICK C. HILL[3], AND KIM H. HAAG[4]
Department of Biology and Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40208

ABSTRACT

Goose Creek is a small, springfed stream beginning to show the influence of urban development along its banks. During the study, 63 species of fishes were collected in Goose Creek and annotations are given for each. Although sedimentation and discharges from sewage treatment plants are beginning to affect the distribution of fishes, the populations were extensive and possibly even enhanced by the additional nutrients that entered the stream during the study period. At present, Goose Creek not only has an assemblage of fishes that inhabit small streams, but is utilized by many species from the Ohio River as a breeding and foraging ground.

INTRODUCTION

Although much is known of the fishes and limnology of the Ohio River and its larger tributaries, little has been published on the numerous small streams directly tributary to the river. Krumholz et al. (1962) examined the fish populations at the mouths of many of the smaller streams in the Louisville area and listed the species inhabiting those areas. Minckley's (1963) study on Doe Run, a torrent spring stream 60 km downstream from Louisville, allows some comparisons with Goose Creek; however, Doe Run is atypical of most streams entering the Ohio River. Other published records of smaller streams along this section of the Ohio are extremely limited.

Within the counties in Kentucky and Indiana comprising the greater metropolitan area of Louisville, 42 first to fourth order (Horton 1945, Kuehne 1962) tributaries enter the Ohio River. In the course of the developing city, most of those tributaries have been drastically altered as habitats for fishes and other aquatic animals, and, unfortunately, we know little of the original faunas and the changes that have occurred.

Goose Creek, although beginning to feel the pressures of urban expansion, is one of the few remaining streams in the Louisville area along which there are relatively undisturbed reaches. This paper provides a detailed account of the fishes and limnological data of Goose Creek so that we may note the changes that take place within the next few years as urbanization continues.

ACKNOWLEDGMENTS

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[1] Contribution No. 184 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

[2] Present address: University of Oklahoma Biological Station, Kingston, Oklahoma 73439.
[3] Present address: Department of Biology, Bloomsburg State College, Bloomsburg, Pennsylvania 17815.
[4] Present address: Department of Biology, Universiti Pertanian, Selangor, Malaysia.

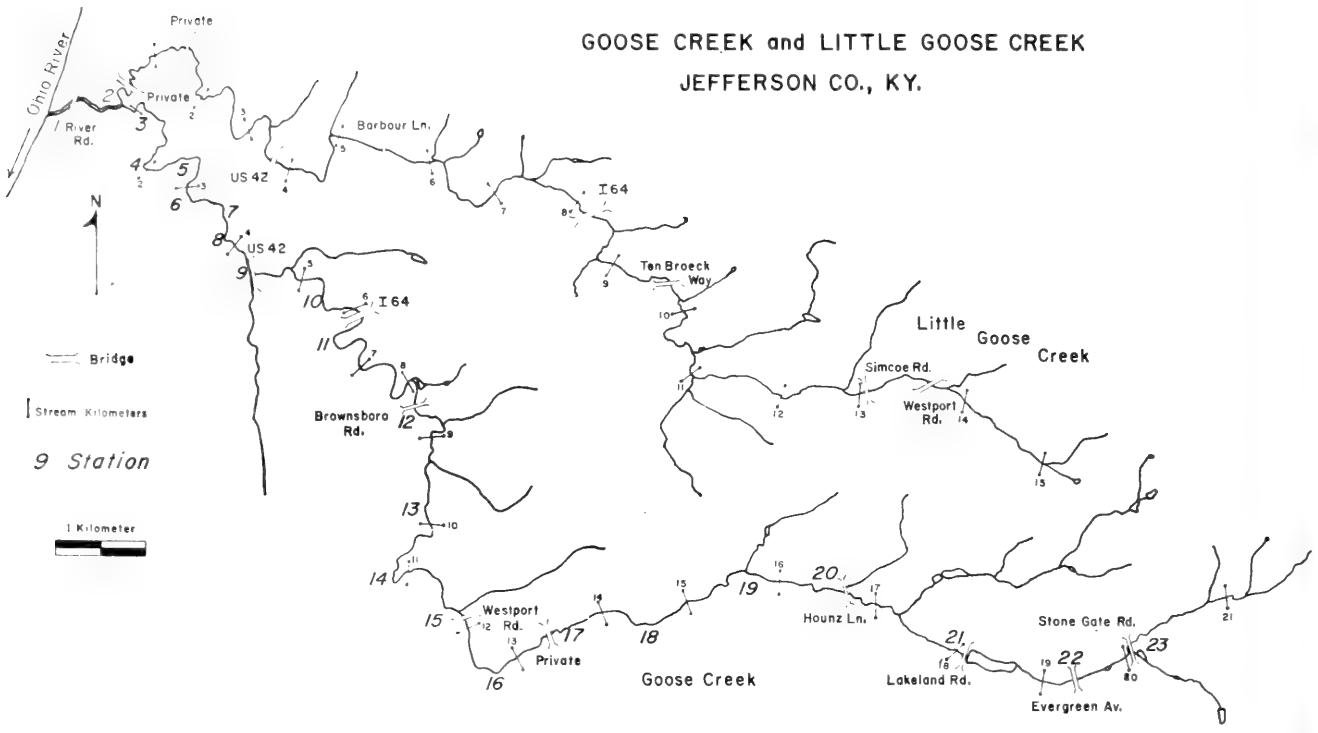

FIG. 1. Map of Goose Creek, Jefferson County, Kentucky, showing locations of sampling stations.

METHODS

From September 1971 to July 1973, fish were collected at least monthly from 23 stations on Goose Creek with occasional samples from Little Goose Creek at Barbour Lane (Fig. 1). A boat equipped with an electrofisher (Larimore et al. 1950) was used to collect fishes from the deeper pools and backwaters. In the shallower portions of the stream, a handheld shocker, common sense seines, bag seines, and dip nets were used in the collections. Both the handheld and boat electrofishers were powered by a Sears 1250-watt alternator. Records and measurements were taken in the field to prevent reduction or elimination of less abundant types; however, representatives of each species were preserved and deposited in the University of Louisville Fish Collections, Louisville, Kentucky.

Identifications were made using Trautman (1957), Clay (1962), and Eddy (1969). With the exception of *Notropis cornutus chrysocephalus* (Resh et al. 1973), both the scientific and common names follow those given by Bailey et al. (1970).

In February, April, July, and October 1972, population estimates were made at Stations 2, 9, and 15 using successive removal (DeLury 1947). Using an IBM-360a computer and programs developed by the Water Resources Laboratory, University of Louisville, weights (kg/ha) and numbers (no/ha) were calculated for each population estimate.

Physical and chemical parameters of Goose Creek were analyzed following the procedures given in *Standard Methods for the Examination of Waste and Waste Water* (American Public Health Association 1971). Discharge, conductivity, pH, total alkalinity, dissolved oxygen, and chlorine were measured in the field.

In addition to the data from this study, a collection by Krumholz et al. (1962) in June 1958, Cat. No. 9228, University of Louisville, from the area of Station 2 was used as a comparison. Field notes were supplied by Krumholz.

STUDY STREAM

At its mouth, Goose Creek (Fig. 1) is a fourth order (Horton 1945, Kuehne 1962) tributary to the Ohio River that drains approximately 60 km^2 of woods, fields, and residential areas in northeastern Jefferson County, Kentucky. Arising near Anchorage, Kentucky, the main stem flows west

then northwest for approximately 22 km. The principal tributary, Little Goose Creek, parallels Goose Creek for more than 15 km and joins the main stem 0.8 km upstream from the Ohio River.

Goose Creek can be divided into 4 distinct regions by physical characteristics and by the extent of urban development. Stations 1 and 2 are in backwaters of the Ohio River, with Station 1 extending from the mouth to the River Road bridge. During the summer, numerous boats are moored along the banks and it is common to see much of the surface covered by gasoline and oil. The boat traffic and wakes from passing barges on the Ohio River often cause considerable turbulence throughout this station. Station 2 essentially is a continuation of Station 1; however, the bridges at River Road coupled with several large log jams provide a barrier against turbulence from the mouth. Station 2 extends from the River Road bridges to the confluence of Goose and Little Goose creeks. This portion of the backwater is 10–20 m wide and 2–7 m deep with a substrate of deep silt to hard mud with occasional patches of sand. The riparian lands of Stations 1 and 2 are primarily pasturage.

At the confluence of the 2 streams, there is a shallow mud riffle distinctly separating the backwater from the continuous pool stations. The pool, Stations 3–9, is in the floodplain of the Ohio River, ranging from 10 to 2 m wide and from 3 to 0.5 m deep over a substrate of hard mud with occasional deposits of silt and sand. Individual stations were created by dividing the long pool into 7 sections, each approximately 250 m long. Station 9 consists of 7 small pools separated by shallow sand riffles. This station resembles the riffle pools of Stations 10–15; however, with the slightest high water, and for some time after each rain, Station 9 becomes indistinguishable from the long pool. There has been little urban development along this portion of the stream and it contains some very old undisturbed stands of cottonwood, sycamore, maple, and walnut.

The stream at Stations 10 to 15 flows over Lower and Middle Silurian limestones and Corydon soils (McFarlan 1943). Bottom materials are gravel and rubble with occasional outcroppings of bedrock. This section is characterized by numerous pools up to 5 m wide, 20 m long, and 1 m deep connected by fast-flowing riffles. A few small farms border the stream between Stations 12 and 15, but, although there are several private homes along the creek, the area has not been developed extensively.

In its upper 10 km (Stations 16–23), the stream flows over bedrock of Middle Devonian limestone and Lower and Middle Silurian shales, limestones, and shaley limestones (McFarlan 1943). In most places, the stream is no more than a few centimeters deep with occasional gravel bottomed pools up to 0.5 m deep. Above Station 15, urban development has increased rapidly in the past 20 years. U. S. Geological Survey maps (corrected in 1950) showed fewer than 100 homes and buildings within 1 km of Goose Creek. By 1971, the number of homes and buildings within 1 km of the creek had increased to more than 300 with an additional 1,000 new buildings within the drainage basin.

Although the stream bed at Stations 16–23 had not been changed greatly, it now flows in and around numerous apartment complexes, back yards, schools, and small parks. Though many of the private homes are 20 to 30 years old, most of the schools and apartment complexes have been constructed within the past 10 years. To handle wastes from this developing area, 2 municipal sewage treatment plants and 19 package treatment plants were emptying their effluents into Goose and Little Goose creeks as of late 1972.

There is little aquatic vegetation along most sections of Goose Creek, though many of the pools are lined with duckweed *Lemna minor* during late summer. The major components of the benthic invertebrate fauna consist of *Lirceus* spp. and *Asellus militaris* (Isopoda); *Gammarus* sp. and *Crangonyx* sp. (Amphipoda); *Baetis* spp. and *Stenonema* spp. (Ephemeroptera);

TABLE 1.—PHYSICAL AND CHEMICAL PARAMETERS OF GOOSE CREEK AT STATIONS 2, 9, AND 15. NUMBER OF SAMPLES IN PARENTHESES

	Station 2		Station 9		Station 15	
	Range	Mean	Range	Mean	Range	Mean
Discharge (m^3/sec)	——	——	0.14–0.68	0.30 (10)	0.06–0.38	0.12 (4)
Turbidity (SiO_2 ppm)	17–145	34 (11)	9–140	25 (11)	15–298	145 (4)
Conductivity (μmho/cm)	275–410	350 (8)	380–475	430 (8)	380–440	400 (4)
pH	6.2–7.8	— (8)	7.0–7.6	— (8)	7.2–7.6	— (4)
Total hardness (ppm)	132–168	150 (8)	140–200	175 (8)	120–183	170 (4)
Total alkalinity (ppm)	82–125	98 (8)	129–168	152 (8)	140–168	152 (4)
Dissolved oxygen (% sat)	56–72	— (14)	100–140	— (14)	100–108	— (4)
Calcium (ppm)	32.2–44.8	36.8 (8)	40.5–55.0	50.2 (8)	40.2–48.1	45.2 (4)
Magnesium (ppm)	9.1–13.6	12.1 (8)	10.2–17.9	15.6 (8)	6.1–15.3	11.5 (4)
Iron (ppm)	——	0.0 (1)	——	0.3 (1)	——	0.6 (1)
Sulfate (ppm)	8.0–75.0	24.0 (8)	6.0–67.0	23.0 (8)	27.3–73.2	44.5 (4)
Nitrate (ppm)	0.52–17.2	3.4 (8)	5.0–214.3	47.6 (8)	6.5–250.0	68.7 (4)
Nitrite (ppm)	0.00–0.08	0.01 (8)	0.00–1.60	0.31 (8)	0.03–2.19	0.77 (4)
Chlorine (ppm)	0.0–tr	0.0 (8)	0.0–0.5	0.2 (8)	0.2–0.8	0.5 (4)
Total phosphate (ppm)	1.0–5.2	3.6 (8)	1.8–19.5	8.3 (8)	3.7–23.7	9.1 (4)
Temperature (°C)	5–28	13.6 (21)	4–25	13.0 (21)	6–22	14.0 (4)

Cheumatopsyche spp. (Trichoptera); *Simulium vittatum* and several genera of Chironomidae (Diptera); *Stenelmis sexlineata* (Coleoptera); and *Physa integra*, *Sphaerium* spp., and *Corbicula manilensis* (Mollusca). Though occasional shells of *Anodonta grandis* were noted, no live unionids were found.

A summary of the physical and chemical characteristics of Goose Creek is given in Table 1. The discharges from tributaries and effluents during 1972 were composed primarily of ground water, with more than half the volume coming from 18 major tributary springs. In the period of lowest recorded flow (17 August 1972), approximately a third of the total discharge at Station 9 was estimated to come from the municipal and package sewage treatment plants. Because Station 2 is in the backwater of the Ohio River, discharge could not be measured satisfactorily. The net flow in the backwater is quite small and results in stagnation during the summer.

Most chemical properties are well within the ranges given for other streams in this area of Kentucky (Minckley 1963, Neff and Krumholz 1973, Krumholz and Neff 1975). Except in the backwater, oxygen levels were at or above saturation. Levels of nitrites, nitrates, and total phosphates occasionally were quite high because of inefficient operation of one or more treatment plants; however, no fish kills were reported or observed.

The stream always is slightly turbid and colored. After each rain, the turbidity increases rapidly, particularly at Station 15 because of construction along the upper portions of Goose Creek.

The distribution of water temperatures for Goose Creek at Stations 2, 9, and 15 are shown in Fig. 2. The springs keep the water temperature below air temperature in the summer and rarely is there ice during winter. The temperatures at Station 2 reflect the temperatures of the Ohio River, i.e., elevated in summer as a result of little net flow.

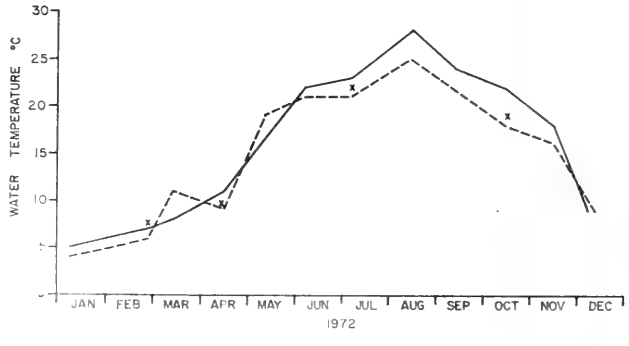

FIG. 2. Water temperatures of Goose Creek, Jefferson County, Kentucky, during 1972: Station 2 (——), Station 9 (– – –) and Station 15 (x).

ANNOTATED LIST OF FISHES

Sixty-three species representing 37 genera and 15 families of fishes were collected. The following list includes the species from Goose Creek and 2 species collected only from Little Goose Creek. Those marked with an asterisk (*) were taken also in the 1958 collection (UL 9228) from Station 2, and all species taken then were collected during this study.

LEPISOSTEIDAE

Lepisosteus osseus. Longnose gar.—Small specimens up to 200 mm occasionally taken from lower stations. Most abundant in early fall. Adults abundant in Ohio River but rarely enter Goose Creek.

Lepisosteus platostomus. Shortnose gar.—One 320-mm adult taken in fall from backwater area.

ANGUILLIDAE

Anguilla rostrata. American eel.—One large specimen netted after being injured by boat.

CLUPEIDAE

Alosa chrysochloris. Skipjack herring.—Large specimens occasionally taken from backwater area. Common in Ohio River but rarely enters Goose Creek.

Dorosoma cepedianum. Gizzard shad*.—Abundant from Stations 1 to 15. Both an immigrant from the Ohio River and a permanent resident in Goose Creek. Large schools containing several hundred young of the year often seen. In fall, schools of several hundred adults enter Goose Creek from the Ohio River to forage in the lower reaches of the stream.

ESOCIDAE

Esox americanus vermiculatus. Grass pickerel.—Two small specimens taken from backwater area.

CYPRINIDAE

Campostoma anomalum. Stoneroller.—Present in most collections from Stations 9 to 20. Most abundant in deeper pools from Stations 9 to 15. Breeding not observed anywhere in the stream, but tuberculate males had freely flowing milt until until early June.

Carassius auratus. Goldfish.—Occasionally taken from backwater area. One large specimen weighed over 6 kg.

Cyprinus carpio. Carp*.—Abundant in lower reaches of stream. Large gravid females entered from the Ohio River during early spring. Males rarely taken. A second population of 1-, 2-, and 3-year-old fish was present at Stations 13 to 16 in pools below major sewage effluents.

Ericymba buccata. Silverjaw minnow.—Not abundant. Collected from pools at Stations 9 to 15.

Hybopsis storeriana. Silver chub*.—One specimen taken from backwater.

Notemigonus crysoleucas. Golden shiner*.—Two specimens, one from Station 3 and another from Station 9.

Notropis ardens. Rosefin shiner.—Occasional specimens taken from Stations 10 to 15. One male with tubercles and in breeding coloration taken in early May. No breeding observed.

Notropis atherinoides. Emerald shiner.—Most abundant fish in stream. Schools containing several thousand fish were present throughout the year. Numbers decreased from Stations 1 to 9. Replaced at Station 9 by the bluntnose minnow.

Notropis blennius. River shiner*.—Occasional immigrants from the Ohio River taken from backwater area.

Notropis cornutus chrysocephalus. Striped shiner.—Occasional specimens taken from pools at Stations 9 to 15.

Notropis spilopterus. Spotfin shiner.—Taken with, but not as abundant as, the rosefin or striped shiners.

Notropis stramineus. Sand shiner.—One specimen taken from backwater area.

Pimephales notatus. Bluntnose minnow*.—

Most abundant species above Station 9. Breeding observed in early May in tributary to Station 15.

Rhinichthys atratulus. Blacknose dace.—Abundant in riffles and tributaries at Stations 13 to 16. Breeding observed in early June in shallow pools with sand and fine gravel.

Semotilus atromaculatus. Creek chub.—Occasionally taken between Stations 9 and 16. Large, tuberculate males taken in early May but no spawning observed.

CATOSTOMIDAE

Carpiodes carpio. River carpsucker*.—Large specimens taken from backwater area. Very abundant in the Ohio River.

Carpiodes cyprinus. Quillback.—Four specimens taken in backwater area.

Catostomus commersoni. White sucker*.—Occasionally taken with golden redhorse and spotted sucker from Stations 1 to 9. Replaces those species above Station 9 where it is quite abundant. Breeding observed in late May over riffles at Stations 13, 14, and 15. Very tolerant of sewage effluents entering around those stations.

Hypentelium nigricans. Northern hog sucker.—Very common in the riffles at Stations 9 to 15. Breeding observed in early April. Young of the year abundant in shallow areas of pools by first of August.

Ictiobus bubalus. Smallmouth buffalo.—Three large specimens taken from backwater area.

Ictiobus niger. Black buffalo.—Several large specimens taken throughout the year from backwater area.

Minytrema melanops. Spotted sucker*.—Most abundant catostomid at Stations 1 to 9. Often taken in association with golden redhorse and white sucker. Breeding observed in riffles at Station 9. Young do not leave breeding area until second or third year.

Moxostoma anisurum. Silver redhorse.—One small specimen taken from backwater area.

Moxostoma carinatum. River redhorse.—One large specimen taken from backwater area.

Moxostoma duquesnei. Black redhorse.—Occasional large specimens taken at Stations 1 to 5.

Moxostoma erythrurum. Golden redhorse*.—Common in deeper pools at Stations 1 to 9. Most abundant below the log jams at Stations 4, 5, and 6. Breeding observed in early May in riffles at Station 9.

ICTALURIDAE

Ictalurus melas. Black bullhead*.—Common in pools at Stations 9 to 15. Occasionally taken from backwater area.

Ictalurus natalis. Yellow bullhead.—One large specimen taken from deep pool at Station 15.

Ictalurus nebulosus. Brown bullhead.—Two specimens, one each at Stations 9 and 15.

Ictalurus punctatus. Channel catfish.—Specimens up to 2 kg common in early spring at Stations 1 to 4. Most abundant when Ohio River rises.

Noturus gyrinus. Tadpole madtom*.—Occasionally taken with the brindled madtom at Stations 2 to 9.

Noturus miurus. Brindled madtom.—Occasionally taken at Stations 2 to 9.

Pylodictis olivaris. Flathead catfish.—One large specimen taken from backwater area.

APHREDODERIDAE

Aphredoderus sayanus. Pirate perch.—Three specimens taken from backwater area.

CYPRINODONTIDAE

Fundulus notatus. Blackstripe topminnow*.—Common from Stations 1 to 16. Most abundant in areas of little or no flow. Specimens were observed but not collected at

Stations 1 to 9 as this species is resistant to electrofishing gear.

POECILIIDAE

Gambusia affinis. Mosquitofish.—Common throughout length of stream. Most abundant in patches of duckweed.

PERCICHTHYIDAE

Morone chrysops. White bass.—Several small specimens taken in early spring from backwater area.

CENTRARCHIDAE

Ambloplites rupestris. Rock bass.—Collected in deeper pools at Stations 2 to 15 but never abundant.

Lepomis cyanellus. Green sunfish*.—Several large specimens taken at Stations 2 to 15.

Lepomis gulosus. Warmouth*.—Taken in moderate numbers from deeper pools at Stations 2 to 15.

Lepomis humilis. Orangespotted sunfish*.—Four specimens taken at Stations 2 to 5.

Lepomis macrochirus. Bluegill*.—Very abundant and taken at all stations. Young of the year and adults present together around stumps, log jams, and undercut areas of the bank. Nests built and spawning observed at Stations 9 to 16 in late June.

Lepomis megalotis. Longear sunfish*.—Abundant and usually taken with bluegill. Not found above Station 16. Fish active on nests; spawning observed at same time and in same pools as bluegill. Young of the year taken from backwater area in early August.

Lepomis microlophus. Redear sunfish.—Occasionally taken at Stations 2 to 15 with bluegill and longear sunfish.

Micropterus dolomieui. Smallmouth bass.—Five small specimens taken at backwater area.

Micropterus punctulatus. Spotted bass*.—Several small specimens taken at Stations 2 to 9 with occasional specimens taken from deep pools at Stations 11 and 15. Not as abundant in backwater area where largemouth bass was dominant.

Micropterus salmoides. Largemouth bass*.—Most common of the 3 blackbasses. Several up to 1.3 kg taken from backwater area. Found in deeper pools at Stations 1 to 15. Spawning observed at Stations 10 and 11 in early June.

Pomoxis annularis. White crappie.—Occasional specimens taken at Stations 2 to 15.

Pomoxis nigromaculatus. Black crappie.—One large specimen taken from backwater area.

PERCIDAE

Etheostoma blennioides. Greenside darter.—Three specimens taken from Little Goose Creek.

Etheostoma caeruleum. Rainbow darter.—Abundant in riffles at Stations 9 to 15. Breeding observed in deeper areas of riffles during late April.

Etheostoma flabellare. Fantail darter*.—Most abundant of the darters. Present in the riffles at Stations 9 to 23. Males with breeding colors and tubercles present in April. Breeding not observed.

Etheostoma nigrum. Johnny darter.—A few specimens taken from Little Goose Creek.

Percina caprodes. Logperch.—Three large specimens taken from backwater area.

Stizostedion canadense. Sauger.—A few small specimens taken from backwater area. Common in Ohio River.

SCIAENIDAE

Aplodinotus grunniens. Freshwater drum*.—Abundant in backwater area during spring. Several also taken at Stations 3 to 9.

COTTIDAE

Cottus carolinae. Banded sculpin.—Five specimens taken from Little Goose Creek.

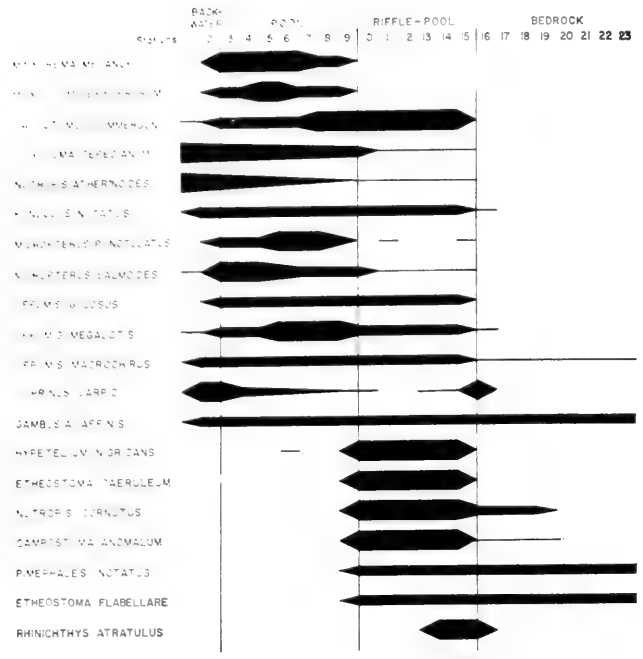

FIG. 3. Distribution of the common fishes in Goose Creek, Jefferson County, Kentucky. Width of line represents relative abundance of a species but not relationships between species.

DISCUSSION

The fish populations of Goose Creek do not differ notably from those of other north-central Kentucky streams (Charles 1957, Turner 1959, Minckley 1963, Hoyt et al. 1970). Distribution and habitats of the species were similar to the descriptions by Forbes and Richardson (1920), Trautman (1957), and Minckley (1963); and all species collected in Goose Creek had been reported previously from Ohio River tributaries by Gerking (1945), Trautman (1957), Krumholz et al. (1962) and others.

Physically, the stream can be divided into 4 distinct regions each with its characteristic species. Fig. 3 depicts the range and relative abundance of the more abundant fishes in each region of Goose Creek during 1972. Only *Lepomis macrochirus* and *Gambusia affinis* were collected at every station. Other than *Dorosoma cepedianum* and *Notropis atherinoides*, very few fish of any species were collected at Station 1. Boat traffic within that section of the creek and the wakes from barges and other boats on the Ohio River together with the extremely silty substrate was not favorable for either the stream or river fishes. The large log jams at the foot of Station 2 provided a good habitat for *Cyprinus carpio* and the larger Centrarchidae. The only sport fishing ever observed on Goose Creek was at Station 2 where many people fished from the River Road bridges and from the banks; however, no creel census was attempted. Of the 63 species in Goose Creek, 46 were collected in the backwater of Stations 1 and 2. Twenty of the 46 were recorded only from the backwater, most of which were waifs from the Ohio River including *Morone chrysops*, *Pylodictis olivaris*, *Moxostoma carinatum*, *Ictiobus bubalus*, and others.

Above Station 2 there was a more orderly longitudinal succession of stream fishes. Most species were confined to or were most abundant in one particular region of the stream. *Minytrema melanops* and *Moxostoma erythrurum* were most numerous in Stations 1 to 6 and were replaced in the riffle–pool stations by *Catostomus commersoni* and *Hypentelium nigricans*. The major predators of the pool stations, *Micropterus punctulatus* and *M. salmoides*, were replaced in the riffle–pool region by *Lepomis megalotis* and *L. gulosus*. The most abundant species of the backwater and pool, *Dorosoma cepedianum* and *Notropis atherinoides*, were replaced in the riffle–pools by *Campostoma anomalum* and *Pimephales notatus*. Only six of the 63 species were taken above Station 15. At the bedrock stations, the water usually was too shallow to support any but the smallest species (Fig. 3). The intrastream distribution of the Goose Creek fishes closely parallels what Minckley (1963) observed for Doe Run.

The species collected in Goose Creek did not utilize the stream equally but can be divided artificially into 3 groups (Table 2): (1) fishes that completed their life cycle in Goose Creek, not normally found in the Ohio River except as waifs; (2) species with permanent populations in both Goose Creek and the Ohio River; and (3) those using Goose Creek during only certain parts of the year or their life cycle. *Noturus* and some *Ictalurus* (bullheads) are

TABLE 2.—CLASSIFICATION OF THE FISHES OF GOOSE CREEK AS INDICATED BY THEIR UTILIZATION OF THE STREAM: (1) THOSE COMPLETING THEIR LIFE CYCLE IN GOOSE CREEK AND NOT NORMALLY FOUND IN THE OHIO RIVER; (2) FISHES WITH PERMANENT POPULATIONS IN BOTH GOOSE CREEK AND THE OHIO RIVER; AND (3) THOSE SPECIES USING GOOSE CREEK DURING ONLY PARTS OF THE YEAR OR OF THEIR LIFE CYCLE

1	2	3
Esox americanus vermiculatus	*Dorosoma cepedianum*	*Lepisosteus osseus*
Campostoma anomalum	*Carassius auratus*	*L. platostomus*
Ericymba buccata	*Cyprinus carpio*	*Anguilla rostrata*
Notropis ardens	*Notropis atherinoides*	*Alosa chrysochloris*
N. cornutus chrysocephalus	*Moxostoma erythrurum*	*Hybopsis storeriana*
N. spilopterus	*Lepomis macrochirus*	*Notemigonus chrysoleucas*
Pimephales notatus	*L. megalotis*	*Notropis blennius*
Rhinichthys atratulus	*L. microlophus*	*N. stramineus*
Semotilus atromaculatus	*Micropterus punctulatus*	*Carpiodes carpio*
Catostomus commersoni	*M. salmoides*	*C. cyprinus*
Hypentelium nigricans	*Pomoxis annularis*	*Ictiobus bubalus*
Minytrema melanops		*I. niger*
Fundulus notatus		*Moxostoma anisurum*
Gambusia affinis		*M. carinatum*
Ambloplites rupestris		*M. duquesnei*
Lepomis cyanellus		*Ictalurus punctatus*
L. gulosus		*Pylodictis olivaris*
Etheostoma blennioides		*Aphrododerus sayanus*
E. caeruleum		*Morone chrysops*
E. flabellare		*Lepomis humilis*
E. nigrum		*Micropterus dolomieui*
Percina caprodes		*Pomoxis nigromaculatus*
Cottus carolinae		*Stizostedion canadense*
		Aplodinotus grunniens

not included in the categories as we felt our collection methods did not sample their populations adequately.

Group (1) is the characteristic stream fauna usually not taken in larger rivers (Trautman 1957, Forbes and Richardson 1920, Krumholz et al. 1962). Of the 63 species collected, 22 fell into this category. Most of them prefer the riffles or small pools between Stations 8 and 15; although, others such as *Minytrema* are backwater and pool fishes.

Group (2) contains 11 of the 63 species. These are river and lake species found year round in the Ohio River and in the backwater and pool stations of Goose Creek. Even though they exist in great numbers in the Ohio River, most, particularly the Centrarchidae, return to a smaller stream to spawn.

Group (3) is composed primarily of those fishes that have sporadic migrations into Goose Creek. As indicated in the annotations, many were represented by 1 specimen or by a single collection, usually from the backwater; and thus, they might not be counted as true residents of the creek. At times, the transient species were quite numerous at Station 2. In the winter and spring, Group (3) species composed as much as 90 percent by weight of the total catch, the most abundant being *Ictalurus punctatus* and *Aplodinotus grunniens*. The transient species utilized Goose Creek for spawning, seasonal foraging, protection during periods of high water, and as a refuge for the young. Group (3) also includes many species that are not common in either Goose Creek or the Ohio River, e.g., *Moxostoma anisurum* and *Aphredoderus sayanus*.

With many of the species that spend their entire life cycles in Goose Creek, there were seasonal intrastream migrations, especially during spawning periods. This was most noticeable in the migrations of

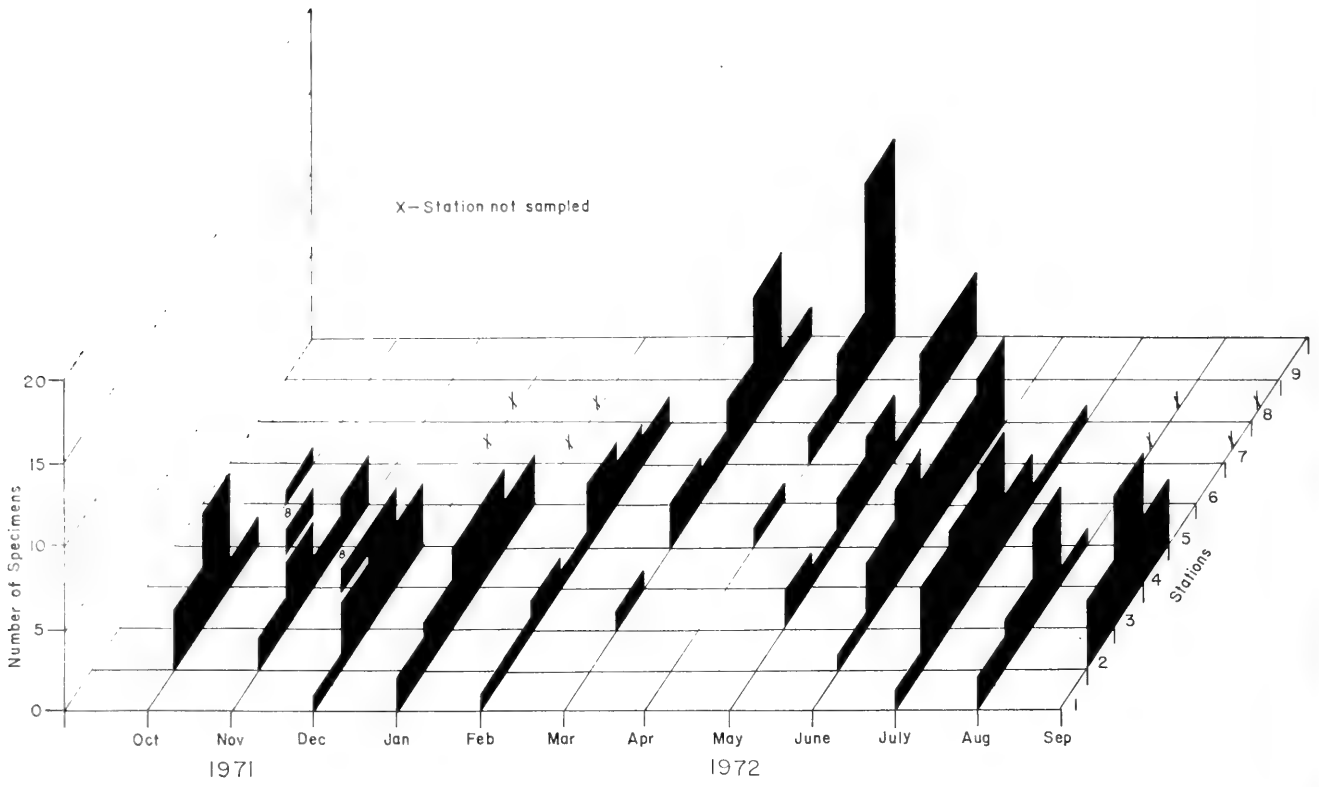

FIG. 4. Average number per month of adult *Minytrema melanops* taken in Stations 1 to 9 in Goose Creek, Jefferson County, Kentucky.

Minytrema melanops (Fig. 4). While 1- and 2-year-old *Minytrema* were found throughout the year at Station 9, adults were present there only in the spring when they usually were absent from the lower pool stations. During the remainder of the year, the adults were most abundant at Stations 2 to 4. This pattern was similar for many Goose Creek species, though the times of migration varied greatly.

TABLE 3.—NUMBER OF SPECIES, ESTIMATED WEIGHTS (KG/HA), AND ESTIMATED POPULATIONS AT 3 STATIONS ON GOOSE CREEK DURING 1972

Station	Month	Number of species	kg/ha	no/ha
2	Feb	8	355	8,490
	Apr	10	265	8,250
	Jul	10	190	8,180
	Oct	9	180	4,270
9	Feb	11	145	5,680
	Apr	14	200	7,150
	Jul	10	130	6,900
	Oct	10	110	4,800
15	Feb	7	65	3,920
	Apr	10	80	4,720
	Jul	7	9	700
	Oct	5	6	660

Standing crops of the fishes from Goose Creek (Table 3) were calculated on the basis of the DeLury (1947) type estimates. Throughout the year, Station 2 had the greatest populations both in terms of numbers and weights. The 355 and 265 kg/ha recorded for February and April reflect the immigration of *Cyprinus carpio*, *Ictalurus punctatus*, and *Aplodinotus grunniens* from the Ohio River.

Station 9 had its greatest populations of fishes in April and July. The high weight in April (200 kg/ha) resulted from the spawning migrations of *Minytrema melanops* and *Moxostoma erythrurum* compared to July when spawners were mainly centrarchids.

Station 15, when sampled in February and April, had numerous schools of minnows, darters, and small sunfishes. In spring 1972, Goose Creek above Station 15 (Westport Road) was channelized and received a tremendous amount of silt from the construction of an apartment complex. The pools, which originally were 0.5 to 1.0 m deep with gravel over bedrock bottoms, had been covered completely by 25 to 30

cm of silt. Population estimates made in July and October 1972 showed a tremendous decrease in both the weights and numbers, although, most species previously collected were still present. The siltation eliminated all darters between Stations 12 and 16.

The effects of numerous sewage treatment plants on Goose Creek have not been investigated adequately enough to allow more than speculation on their present role in the stream ecology. No fish kills were seen by us or were reported during the study period. Even though large amounts of untreated sewage periodically entered Goose Creek, oxygen levels except in the backwater area were always at or above 100 percent saturation (Table 1). At present levels, the amount of sewage entering Goose Creek may be aiding fish production. For the total stream, Goose Creek averaged 143 kg/ha of fish. This is higher than 90 kg/ha determined for the Salt River (Hoyt et al. 1970) and in general is higher than other north-central Kentucky streams cited by Charles (1957) and Turner (1959).

LITERATURE CITED

AMERICAN PUBLIC HEALTH ASSOCIATION. 1971. Standard Methods for the Examination of Water and Wastewater. 13th ed. Amer. Public Health Ass., Washington, D. C. 874 pp.

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd ed. Amer. Fish. Soc. Spec. Publ. 6:1–150.

CHARLES, J. R. 1957. Final report on population manipulation studies in three Kentucky streams. Proc. Southeast. Ass. Game Fish Comm. 11:155–184.

CLAY, W. M. 1962. A field manual of Kentucky fishes. Ky. Dept. Fish Wildl. Res., Frankfort, Ky. 147 pp.

DELURY, D. B. 1947. On the estimation of biological populations. Biometrics 3:145–167.

EDDY, S. 1969. How to know the freshwater fishes. Wm. C. Brown, Co., Dubuque, Iowa. 253 pp.

FORBES, S. A., AND R. E. RICHARDSON. 1920. The fishes of Illinois. Ill. Nat. Hist. Surv., Urbana, Ill. 358 pp.

GERKING, S. D. 1945. The distribution of the fishes of Indiana. Invest. Ind. Lakes Streams 3:283–309.

HORTON, R. W. 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Bull. Geol. Soc. Am. 56:275–370.

HOYT, R. D., S. E. NEFF, AND L. A. KRUMHOLZ. 1970. An annotated list of the fishes from the upper Salt River, Kentucky. Trans. Ky. Acad. Sci. 31:51–63.

KRUMHOLZ, L. A., J. R. CHARLES, AND W. L. MINCKLEY. 1962. The fish population of the Ohio River. *In*: Aquatic life resources of the Ohio River. Ohio River Valley Water Sanit. Comm., Cincinnati, Ohio. 218 pp.

KRUMHOLZ, L. A., AND S. E. NEFF. 1975. Abatement of pollution in Hite Creek, Jefferson and Oldham counties, Kentucky. Trans. Ky. Acad. Sci. 36:25–37.

KUEHNE, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43:608–614.

LARIMORE, R. W., L. DURHAM, AND G. W. BENNETT. 1950. A modification of the electric fish shocker for lake work. J. Wildl. Manage. 14:320–323.

MCFARLAN, A. C. 1943. Geology of Kentucky. Univ. Ky. Press, Lexington, Ky. 531 pp.

MINCKLEY, W. L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildl. Monogr. 11:1–124.

NEFF, S. E., AND L. A. KRUMHOLZ. 1973. A detailed investigation of the sociological, economic, and ecological aspects of proposed reservoir sites in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. 67. 66 pp.

RESH, V. H., R. D. HOYT, AND S. E. NEFF. 1973. The status of the common shiner, *Notropis cornutus chrysocephalus* (Rafinesque), in Kentucky. Proc. Southeast. Ass. Game Fish Comm. 25:550–556.

TURNER, W. R. 1959. Pre-impoundment surveys of six Kentucky streams. Ky. Fish Bull. 24. 43 pp.

TRAUTMAN, M. B. 1957. The fishes of Ohio. Ohio St. Univ. Press, Columbus, Ohio. 683 pp.

Studies on the Passive Transfer via Serum of Immunity to *Hymenolepis nana* in the Mouse *Mus musculus*[1]

SHARON PATTON[2]
Thomas Hunt Morgan School of Biological Sciences, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

Five experiments were conducted to investigate the passive transfer via serum of immunity to *Hymenolepis nana* in the white mouse. Serum collected from mice that received 5,000 *H. nana* eggs by mouth 14 days before bleeding (Type I serum) was used in 3 experiments. Serum collected on Day 28 from mice that received 1,000 eggs on Day 0 and 10,000 eggs on Day 14 (Type I serum) was used in the fourth experiment. Serum collected on Day 42 from mice that received 1,000 eggs on Day 0, 5,000 eggs on Day 14, and 10,000 eggs on Day 28 (Type III serum) was used in the fifth experiment.

The sera were injected intraperitoneally into 6- to 8-week-old mice, and the recipients were challenged orally with 10,000 eggs. Control mice were challenged after the injection of normal serum. Fewer cysticercoids developed in the mice treated with 1 ml of Type I serum immediately prior to the administration of eggs than in controls injected with normal serum before egg administration. The duration of the protection afforded by Type I serum lasted less than 6 hours and was not prolonged by increasing the amount of serum injected to 2 ml. The injection of Type II and Type III serum extended the protective period to 35 days. The extended period of resistance from Type II and Type III sera suggests an anamnestic response following a second exposure to eggs. The transient nature of the protection indicated that the passive resistance probably was antibody mediated.

INTRODUCTION

Hymenolepis nana, the dwarf tapeworm of man and rodents, is an exception among cestodes in that it does not require an intermediate host although it may utilize one in an alternate indirect life cycle (see Heyneman 1962a for a review). Eggs ingested directly by the vertebrate host hatch in the duodenum and release onchospheres that invade the mucosal lining and develop into cysticercoids in the intestinal villi. The cysticercoids become fully developed in 96 hours, begin leaving the villi at approximately 102 hours, migrate into the ileum, evaginate, attach, and develop into mature worms.

When an infection is induced by eggs, a tissue invasive stage is involved and host resistance to reinfection is acquired. An infection of just 200 to 500 eggs can elicit a lasting immunity, which is first discernible 9 hours after initial infection, marked at 12 hours, and practically absolute after 24 hours (Hearin 1941).

White mice were resistant to a challenge of *H. nana* eggs after intraperitoneal injections of serum from experimentally infected donors (Hearin 1941). It is not clear if this actually demonstrated passive transfer of immunity because the persistence of the protection was not investigated. Weinmann (1966) reported that serum from infected mice had varying degrees of protection against oral challenges of *H. nana* eggs. A humoral basis for the immunity was demonstrated by DiConza (1969) when he found that serum from mice infected with *H. nana* contained IgG (7S) immunoglobulin fraction which had a strong antiparasitic activity against subcutaneously injected, growing *H. nana* larvae. The sera of mice that received a single oral injection of eggs acquired significant immune activity within 7 days; the maximum level was reached at 14 days and maintained until Day 28. The present

[1] From a dissertation submitted to the Graduate School of the University of Kentucky in partial fulfillment of the requirements for the degree of Doctor of Philosophy.
[2] Present address: Department of Veterinary Science, University of Kentucky, Lexington, Kentucky 40506.

study was conducted to evaluate further the role of serum in the immunity to *H. nana* in mice and to measure the duration of the passively transferred protection.

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MATERIALS AND METHODS

A breeding colony of Swiss albino mice was purchased from Maxfield Supply, Cincinnati, Ohio, established, and maintained under *Hymenolepis* free conditions. Only those animals negative for *H. nana*, as determined by fecal examinations over a 6-week period, were used to establish the initial colonies. The experimental mice were isolated from the colonies when approximately one month old.

Initial infections of mature tapeworms were established from an exogenous source of *H. nana* eggs secured from Carolina Biological Supply Co., Burlington, N. C.; thereafter, hosts with patent infections of worms were killed to obtain eggs. Desired numbers of eggs for administration to experimental animals were prepared by Heynemen's (1962a) egg dilution count. Eggs were administered to the animals via stomach tube while mice were lightly anesthetized with ether. Cysticercoids that developed in the small intestine of infected mice were counted by the method of Hunninen (1935). The following nonparametric statistical tests were used to determine the significance of the observed differences in the numbers of cysticercoids recovered from the serum treated and the nontreated groups: (1) Wilcoxon Rank Sum Test (Wilcoxon et al. 1963) when comparing 2 groups, (2) Kruskal-Walis One-Way Analysis of Variance for Ranks (Spence et al. 1968) when comparing more than 2 groups, and (3) Dunn Multiple Comparison Test for Rank Sums (Dunn 1964).

Serum was obtained from blood drawn from mice by cardiac extravasation. Blood was allowed to clot at room temperature for 1 to 3 hours and the serum separated by centrifugation at 2,500 rpm for 10 min. Serum from within a group of mice was pooled and frozen at –20 C without preservatives. Before inoculation the serum was thawed and mixed thoroughly.

Serum was collected from mice 14 days after an initial infection of eggs or 14 days after a challenge dose of eggs was administered. Three schedules for drawing blood were coordinated with administration of *H. nana* eggs: (1) Type I serum was derived from blood collected on Day 14 from mice that received 5,000 eggs on Day 0, (2) Type II serum was prepared from blood collected on Day 28 from mice that received 1,000 eggs on Day 0 and 10,000 eggs on Day 14, (3) Type III serum was prepared from blood collected on Day 42 from mice that received 1,000 eggs on Day 0, 5,000 eggs on Day 14, and 10,000 eggs on Day 28. Uninfected mice were bled to provide normal sera.

The sera were injected intraperitoneally into 6- to 8-week-old mice. Those mice received an oral challenge of 10,000 eggs at various specified times following serum injection. Control mice were challenged after injection of normal serum. Ninety-six hours after the challenge doses of eggs were administered, cysticercoids in each group were counted as an index of the manifestation of the immune response.

Experimental Design for Type I Serum

In Experiment A, 3 groups of 5 mice each were used. Each mouse received 1 ml of serum. Type I serum was inoculated into the mice of Groups 1 and 2, and normal serum was injected into Group 3 mice. Eggs were administered to the mice of Groups 1 and 3 immediately after injection of serum and to the mice of Group 2, 6 hours after inoculation of serum.

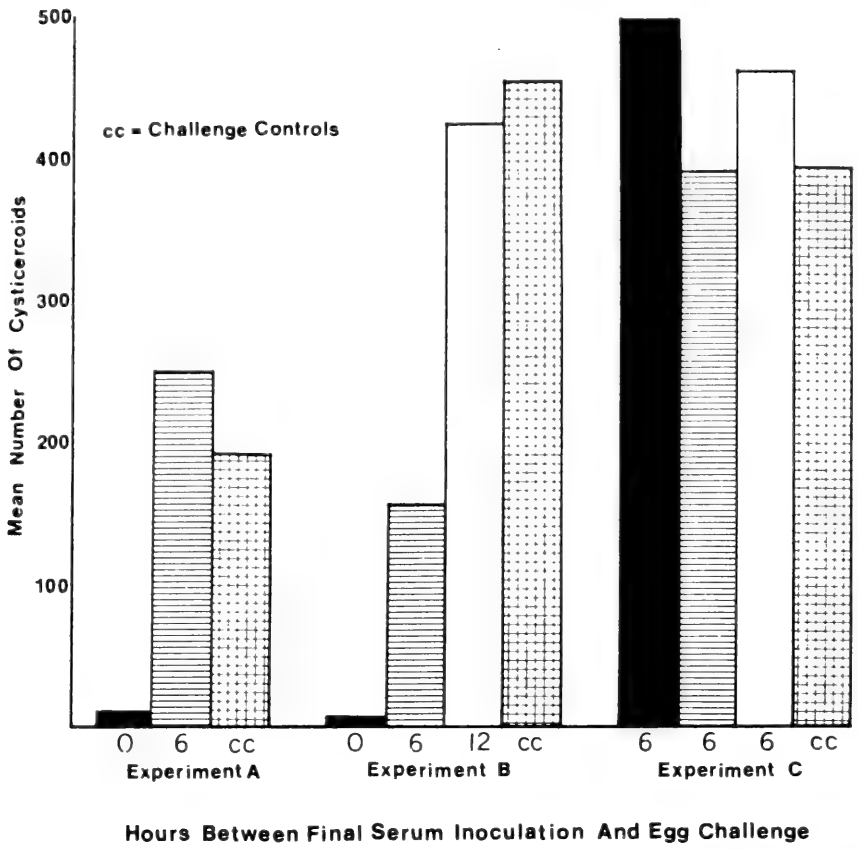


FIG. 1. Effect of intraperitoneal injection of Type I serum on the number of *H. nana* cysticercoids developing in the intestinal villi of white mice following a 10,000-egg challenge.

In Experiment B, 4 groups of 5 mice each were used. Each mouse was inoculated with 2 ml of serum. Type I serum was administered to the mice of Groups 1, 2, and 3, and normal serum was administered to the mice of Group 4. Eggs were administered to the mice of Groups 1 and 4 immediately after injection of serum; to the mice of Group 2, 6 hours after injection of serum; and to the mice of Group 3, 12 hours after injection of serum.

In Experiment C, 4 groups of 5 mice each were used. Each mouse was injected with 0.5 ml of serum on successive days. Group 1 mice received 2 injections of Type I serum; Group 2 mice received 3 injections of Type I serum; Group 3 mice received 4 injections of Type I serum; and Group 4 mice received 4 injections of normal serum. Eggs were administered 6 hours after the last dose of serum to the mice of all groups.

Experimental Design for Type II Serum

In Experiment D, 12 groups of 10 mice each were used. One-half of the mice were injected with 1-ml amounts of Type II serum and the other half were inoculated with 1-ml amounts of normal serum. Eggs were administered immediately, 12 hours, 1, 3, 7, 10, 12, 14, 21, 28, 35, or 42 days after sera were injected.

Experimental Design for Type III Serum

In Experiment E, 3 groups of 10 mice each were used. One-half of the mice were injected with 1-ml amounts of Type III serum and the other half were inoculated with 1-ml amounts of normal serum. Eggs were administered 28, 35, or 42 days after the sera were injected.

RESULTS

In Experiment A, there was a significant difference in the number of cysticercoids that developed among the 3 groups ($P = 0.01$). Fewer cysticercoids developed in those treated with the Type I serum immediately prior to egg inoculation (Fig. 1). The protective effect lasted less than 6 hours ($P = 0.1$).

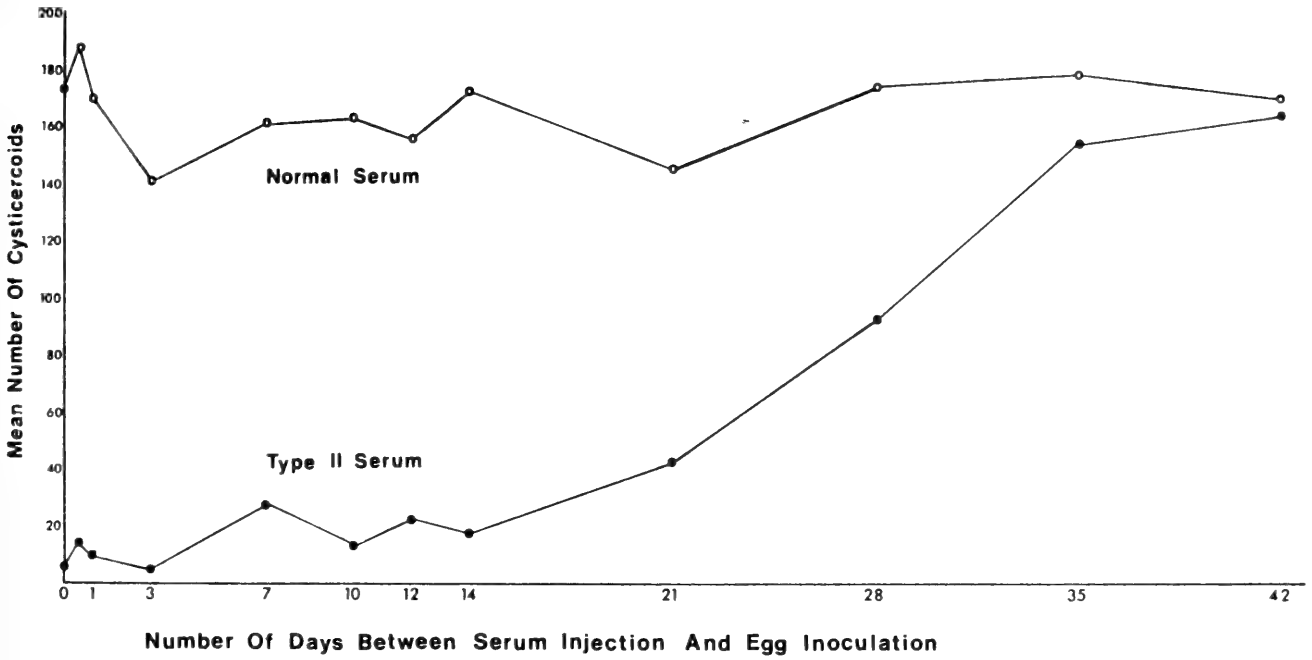


FIG. 2. Effect of intraperitoneal injection of 1-ml doses of Type II serum on the number of *H. nana* cysticercoids developing in white mice after a 10,000-egg challenge at intervals during a 42-day period after serum injection (Experiment D).

Similarly, in Experiment B there was a significant difference in the numbers of cysticercoids that developed among the 4 groups of mice ($P = 0.01$). Fewer cysticercoids developed in the mice of Group 1 which were treated with Type I serum and inoculated with eggs immediately thereafter ($P = 0.1$). As shown in Fig. 1, the number of cysticercoids was reduced in the group of mice given eggs 6 hours after the injection of serum; however, this was not statistically significant ($P = 0.1$).

The number of cysticercoids that developed in the mice of the 4 groups of Experiment C were not significantly different ($P = 0.1$); therefore, the multiple injections were not effective against the *H. nana* challenge (Fig. 1).

The mean numbers of cysticercoids that developed in each group of mice of Experiment D are shown in Fig. 2. The numbers of cysticercoids in the animals injected with Type II serum and inoculated with eggs immediately to 28 days later were significantly fewer than the numbers in the control animals that received eggs at the same time intervals after the injection of normal serum ($P = 0.01$). Although still detectable, that difference was not as marked at 35 days ($P = 0.1$), and had disappeared by 42 days ($P = 0.1$) (Fig. 2).

The mean numbers of cysticercoids that developed in each group of mice of Experiment E are shown in Fig. 3. A similar number of cysticercoids developed in each group that received the normal serum ($P = 0.1$), but there was a significant difference among groups that received the Type III serum ($P = 0.01$). Fewer cysticercoids developed in the animals treated with Type III serum 28 days ($P = 0.01$) and 35 days ($P = 0.1$) prior to the administration eggs than in the corresponding control groups. There was not, however, a significant difference between the numbers of cysticercoids that developed in the 2 42-day groups ($P = 0.1$).

DISCUSSION

Type I serum collected from donor white mice 14 days after an initial dose of eggs and injected intraperitoneally into homologous recipients was effective for less than 6 hours in decreasing the number of cysticercoids that developed following a chal-

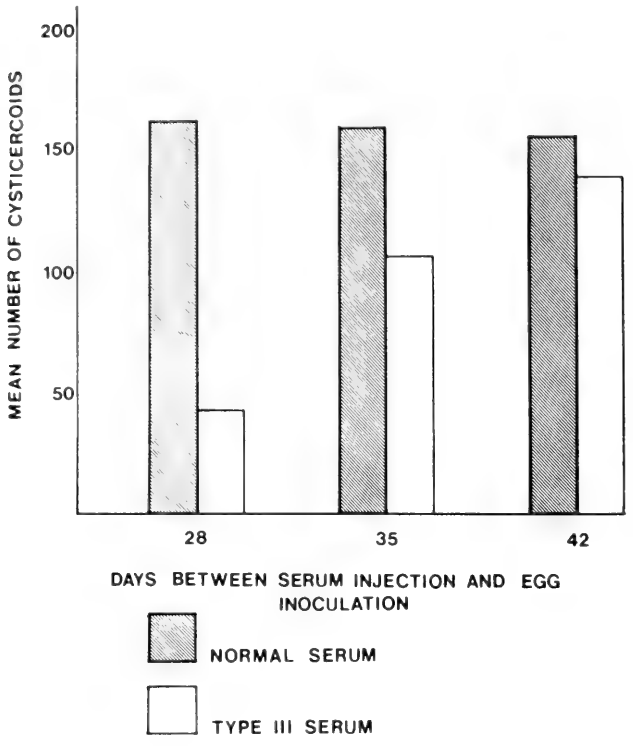


FIG. 3. Effect of intraperitoneal injection of 1-ml doses of Type III serum on the number of *H. nana* cysticercoids developing in white mice after a 10,000-egg challenge at intervals during a 42-day period after serum injection (Experiment E).

lenge dose of eggs. The protective value of Type I serum was transient and so low that daily injection of 0.5 ml was ineffective. One ml of the serum was a sufficient quantity to protect mice against a challenge exposure of 10,000 eggs.

Both Type II and Type III sera, collected after additional challenge doses of eggs, extended the period of protection to 35 days, and the protection was dissipated gradually. The increased efficacy of these sera suggest an anamnestic response following a second exposure to eggs. The prolonged period of protection and the decrease in total numbers of cysticercoids developing in the animals treated with Type II or Type III sera as compared to the recipients of Type I serum indicates that the former response could occur in naturally acquired immunity against *H. nana.*

Hearin (1941) transferred resistance against a challenge dose of *H. nana* eggs to susceptible mice by prior injection of them with multiple doses of serum from infected white mice. The persistence of the protection was not investigated; so it is possible that the immunity demonstrated was stimulated by antigen (penetration or metabolic enzymes of the worm) transferred with the serum, rather than a passive resistance related to the antibodies present. In the present investigations, the rapid onset of the protection after the injection of the sera and the transient nature of the protection confirmed that immunity against *H. nana* can be transferred passively with serum from infected mice. Weinmann (1966) found the protection afforded by serum from infected mice to be variable in passive transfer experiments; however, the interval between the infection of the donor mice and the collection of their blood varied from 2 to 6 weeks rather than the 14-day interval indicated by DiConza (1969).

Serum injected into the peritoneal cavities of mice should reach the circulation by way of lymphatics in a very short period of time (Weiss 1972). In the present study, it is presumed that the time necessary for the protective factors of the immune serum to reach the intestinal area was compatible with the time it took the eggs to hatch and the onchospheres to reach the intestinal villi. In active immunity acquired by infection, the majority of onchospheres in a second dose of eggs are unable to penetrate the intestinal villi (Bailey 1951). According to Weinmann (1966), immune serum also inhibits the onchosphere at the mucosal surface, presumably by extravasation of passively transferred antibody into the intestinal lumen or by adsorption of the antibody onto the tissues of the host. Therefore, the protective property of the serum would have to be present within at least the first 12 hours after the administration of eggs.

The half-life of IgG, IgA, and IgM is on the order of 4, 1.2, and 0.5 days, respectively (Fahey and Sell 1965). If, indeed, the protection observed in the present investigations was due to antibody, the titer of Type I serum was low, as indicated by the fact that the protection had dis-

appeared in 6 hours. Shorter time periods were not tested, so the exact duration of the protection is unknown. Increasing the amount of serum injected from 1 ml to 2 ml did not prolong the period of protection; however, a higher dose of eggs was not tested, and it is possible that an increased amount of serum would prevent the development of larger doses of eggs.

In a naturally acquired infection, reinfection immunity may be detected by 12 hours and become very strong by 24 hours (Hearin 1941; Bailey 1951; Weinmann 1958; Heyneman 1962a, 1962b). This rapid onset seems to obfuscate the role of antibody in the initial onset of naturally acquired immunity. Twelve hours may be insufficient time for a detectable antibody response. Heyneman (1962b) proposed that detection of rapid antibody production in serum is delayed by the large dilution factor, but in cases where the intestinal mucosa is directly challenged in the absence of a blood borne transport mechanism, a 12- to 24-hour period may be possible.

Okamoto (1970) and Okamoto and Koizumi (1972) demonstrated that the thymus was involved in the development of acquired immunity to *H. nana*. Levine and Claman (1970) indicated that more than one cell type was necessary for at least some of the antibody responses in the mouse. The present study shows that protective humoral factors (possibly protective antibody) are present in mice following *H. nana* infection. Although antibodies may not be the major agent working against *H. nana* challenge in naturally occurring infections, a T-cell-dependent antibody response is possible and should be investigated further.

LITERATURE CITED

BAILEY, W. S. 1951. Host–tissue reactions to initial and superimposed infections with *Hymenolepis nana* var. *fraterna*. J. Parasitol. 37: 440–444.

DICONZA, J. J. 1969. Protective action of passively transferred immune serum and immunoglobulin fractions against tissue invasive stages of the dwarf tapeworm, *Hymenolepis nana*. Exp. Parasitol. 25:368–375.

DUNN, O. J. 1964. Multiple comparisons using rank sums. Technometrics 6:241–252.

FAHEY, J. L., AND S. SELL. 1965. The immunoglobulins of mice. V. The metabolic (catabolic) properties of five immunoglobulin classes. J. Exp. Med. 122:41–58.

HEARIN, J. T. 1941. Studies on the acquired immunity to the dwarf tapeworm, *Hymenolepis nana* var. *fraterna* in the mouse host. Amer. J. Hyg. 33:71–87.

HEYNEMAN, D. 1962a. Studies on helminth immunity: I. Comparison between lumenal and tissue phases of infection in the white mouse by *Hymenolepis nana* (Cestoda: Hymenolepididae). Am. J. Trop. Med. Hyg. 11:46–63.

———. 1962b. Studies on helminth immunity. IV. Rapid onset of resistance by the white mouse against a challenging infection with eggs of *Hymenolepis nana* (Cestoda: Hymenolepididae). J. Immunol. 88:217–220.

HUNNINEN, A. V. 1935. A method of demonstrating cysticercoids of *Hymenolepis fraterna* (*H. nana* var. *fraterna* Stiles) in the intestinal villi of mice. J. Parasitol. 21:124–125.

LEVINE, M. A., AND H. N. CLAMAN. 1970. Bone marrow and spleen: dissociation of immunologic properties by cortisone. Science 167: 1515–1517.

OKAMOTO, K. 1970. *Hymenolepis nana*: depression and restoration of acquired immunity in neonatally thymectomized mice. Exp. Parasitol. 27:28–32.

———, AND M. KOIZUMI. 1972. *Hymenolepis nana*: effect of antithymocyte serum on acquired immunity in mice. Exp. Parasitol. 32: 56–61.

SPENCE, J. T., B. J. UNDERWOOD, C. P. DUNCAN, AND J. W. COTTON. 1968. Elementary Statistics. 2nd Ed. Meredith Corporation, Educational Division, Appleton-Century-Crofts, New York, N.Y. 245 pp.

WEINMANN, C. J. 1958. Rate of development of acquired immunity to *Hymenolepis nana* var. *fraterna*. J. Parasitol. 44:16 (Ab).

———. 1966. Immunity mechanisms in cestode infections. Pp. 301–320 *In* E. J. L. Soulsby (Ed.). Biology of Parasites. Academic Press, New York, N.Y. 354 pp.

WEISS, L. 1972. The Cells and Tissues of the Immune System. Prentice-Hall, Inc., Englewood Cliffs, N.J. 252 pp.

WILCOXON, F., R. A. WILCOX, AND S. K. KATTI. 1963. Critical Values and Probability Levels for the Wilcoxon Rank Sum Test and the Wilcoxon Signed Rank Test. American Cyanamid Co. and The Florida State University, New York, N. Y., and Tallahassee, Fla. 64 pp.

Pathology in Mice Resulting from Concurrent Infestations with the Bile Duct Dwellers *Fasciola hepatica* (Trematoda) and *Hymenolepis microstoma* (Cestoda)[1]

LARRY N. GLEASON[2]
Department of Parasitology and Laboratory Practice, School of Public Health, University of North Carolina, Chapel Hill, North Carolina 27514

ABSTRACT

Concurrent infestations in white mice were established using infesting doses of 2 *Fasciola hepatica* metacercariae and 10 *Hymenolepis microstoma* cysticercoids. In Sequence I, *F. hepatica* were given on Day 0 and *H. microstoma* on Day 37. *H. microstoma* were given on Day 0 in Sequence II followed by *F. hepatica* on Day 20. In Sequence III, the midacute phases of both infestations coincided, *F. hepatica* being given on Day 0 and *H. microstoma* on Day 15. Pathologies previously described for each infestation were observed in the mice of the concurrent infestation groups and in mice of the single species control groups. In Sequence I, 2 additional pathologies were observed in mice of the concurrent infestation group: (1) the eggs of *F. hepatica* were found in the tissues of the mice and (2) the generalized necrosis in the liver associated with the acute phase of infestation with *F. hepatica* (18–35 days after infestation) was reestablished on Day 60 and continued through Day 120. In Sequence II, the generalized necrosis in the livers of mice of the concurrent infestation group continued through Day 90, 70 days after the infestation with *F. hepatica*. One mouse of the concurrent infestation group in Sequence III was observed to have the eggs of *F. hepatica* in the liver and biliary tissues.

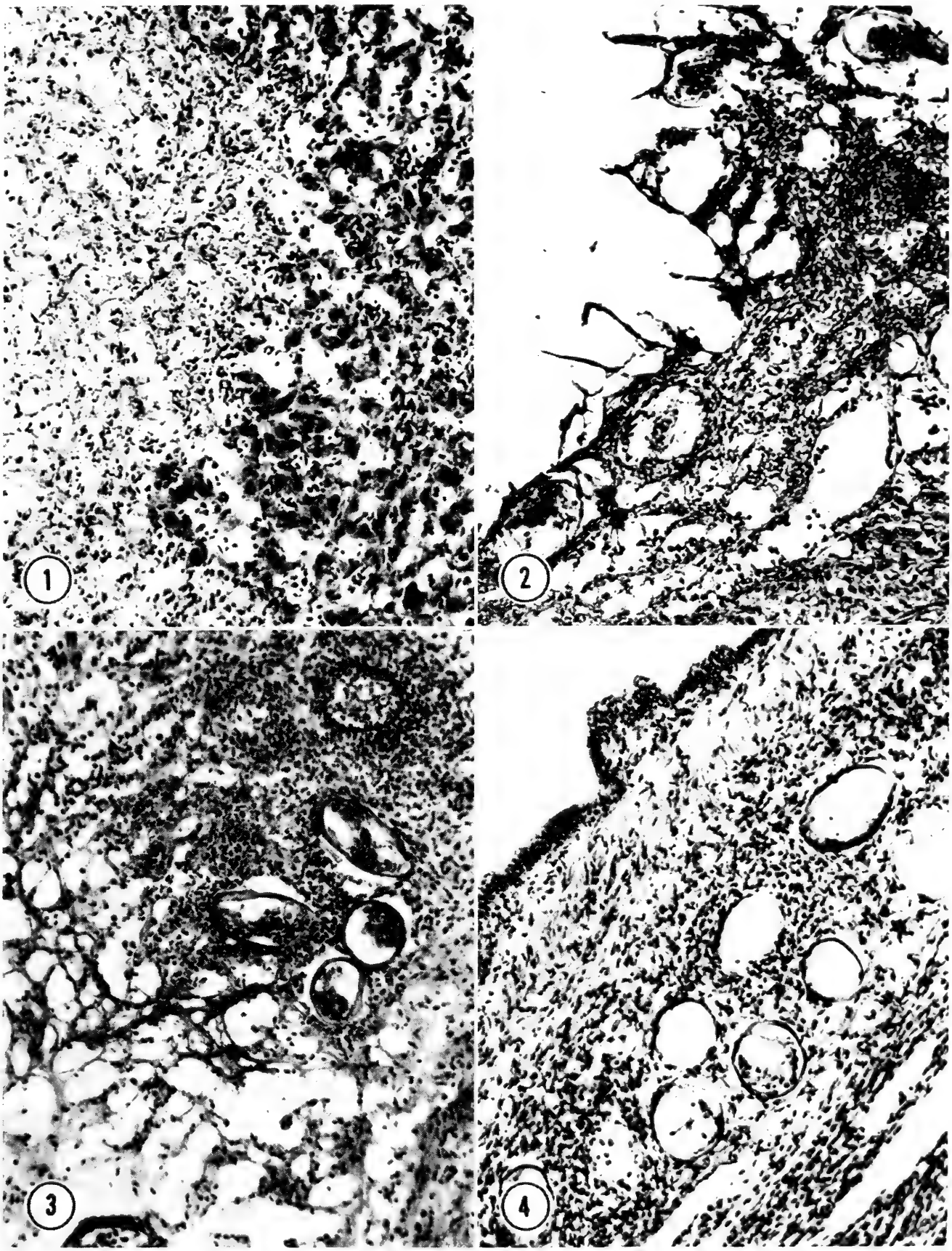
INTRODUCTION

Extensive pathology in the liver is associated with the infestation of mice by 2 bile duct dwellers, the trematode *Fasciola hepatica* and the cestode *Hymenolepis microstoma*. The pathology resulting from the obligatory liver migration by the trematode and its subsequent inhabitation of the common bile duct have been the subject of numerous reports in the literature and have been summarized by Lang (1966, 1967). Lang (1966) divided the course of a primary infestation with *F. hepatica* in mice resulting from a 2-worm infesting dose into 3 phases: (1) the incubation phase (0–17 days after infestation), (2) the acute phase (18–35 days after infestation), and (3) the chronic with repair phase (36–250 days after infestation). During the incubation phase, damage to liver tissue was a direct result of mechanical trauma caused by the migrating worms. Severe liver damage and some mortality were associated with the acute phase of the infestation. Generalized necrosis was present in large areas of the liver and from 30–90 percent of the liver appeared necrotic. The necrosis was associated with lymphocytic infiltrations that were not, generally, located near worm burrows. The chronic phase of the infestation was initiated by the migration of the worms from the liver tissue into the common bile duct. Damaged liver tissue was replaced by regenerated parenchyma and connective tissue. However, the lymphocytic infiltration was maintained.

Although the life cycle of the cestode does not involve a liver migration, the inhabitation of the common bile duct results in extensive liver damage through the release of a toxin by the worms (Simpson and Gleason 1975), and published reports dealing with the pathology associated with the infestation of mice are numerous. These

[1] A portion of a dissertation submitted to the Faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Parasitology and Laboratory Practice, 1969.

[2] Present address: Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101



FIGS. 1–4. Pathology in mice resulting from concurrent infestations with *Fasciola hepatica* and *Hymenolepis microstoma*. Fig. 1. Generalized necrosis in the liver on Day 90. Many lymphocytes are present at the periphery of the necrotic area and in the sinusoids. ×140. Fig. 2. Eggs of *F. hepatica* trapped in serous exudate at region where the epithelial lining of the common bile duct has been eroded away (Day 50). ×140. Fig. 3. Eggs of *F. hepatica* in the tissue of the common bile duct on Day 70. ×140. Fig. 4. Eggs of *F. hepatica* in the wall of the cystic duct on Day 80. ×140.

have been summarized by Gleason (1971). Gleason (1971) divided the course of a primary infestation with *H. microstoma* in mice resulting from a 10-worm infesting dose into 3 phases: (1) incubation phase (0–6 days after infestation), (2) acute phase (7–20 days after infestation), and (3) chronic phase (21–150 days after infestation). During the incubation phase, there was very little damage to the liver. The acute phase was initiated by the rapid formation of focal lesions in the parenchyma of the liver. Those lesions were characterized by degenerated hepatic cells surrounded by infiltrating leukocytes, predominantly neutrophils. During the chronic phase of the infestation, focal lesions were still formed, but apparently at a reduced rate, allowing repair processes to keep pace with lesion formation.

This study presents some additional pathology in mice that results from concurrent infestation with *F. hepatica* and *H. microstoma* and variation in the pathology related to sequence and timing of the infestations.

Acknowledgments

I gratefully acknowledge the assistance of the faculty of the Department of Parasitology and Laboratory Practice throughout this study. Special thanks are due Dr. James R. Hendricks for his guidance, encouragement, and criticism. Dr. Bruce Z. Lang was instrumental in the selection of the problem and his advice and encouragement are gratefully acknowledged. Mr. Merlin D. Gleason supplied the original source of *Fasciola hepatica.*

Materials and Methods

The Swiss white mice used in this study were males, 15–16 weeks old at the beginning of the experiments, from a randomly bred strain maintained in the Department of Parasitology and Laboratory Practice, University of North Carolina, for more than 30 years. The stock of *F. hepatica* was isolated from a naturally infested cow in northern California and maintained in the laboratory as described by Lang (1966). The stock of *H. microstoma* was originally obtained from Dr. Arthur Jones, University of Tennessee, Knoxville, and maintained in the laboratory as described by Litchford (1963).

In Sequence I, an infestation with *H. microstoma* was imposed upon a patent infestation with *F. hepatica.* Each of the 64 mice of the concurrent infestation group and the 32 mice of the *F. hepatica* control group received 2 metacercariae of *F. hepatica* by mouth on Day 0. On Day 37, each of the mice remaining in the concurrent infestation group and the 16 mice of the *H. microstoma* single species control group received 10 cysticercoids of *H. microstoma* by mouth. One mouse from each group was killed to obtain tissues for histologic preparations on the days indicated: concurrent infestation group—Days 37, 44, 48, 50, 60, 70, 80, 90, 100, 110, and 120; *F. hepatica* single species control group—Days 20, 30, 50, 80, and 120; and *H. microstoma* single species control group—Days 50 and 120. During this experimental sequence and those reported below, some mice died as a result of the infestations and some mice were killed to determine worm number, size, and location, as previously reported by Gleason (1974).

In Sequence II, an infestation with *F. hepatica* was imposed upon a patent infestation with *H. microstoma.* The 40 mice of the concurrent infestation group and the 24 mice of the *H. microstoma* single species control group each received 10 cysticercoids of *H. microstoma* on Day 0. Two metacercariae of *F. hepatica* were given to each of the mice in the concurrent infestation group and the 32 mice in the *F. hepatica* single species control group on Day 20. One mouse from each group was killed to obtain tissues for histologic preparations on the days indicated: concurrent infestation group—Days 30, 35, 40, 45, 50, 60, 70, 90, and 100; *H. microstoma* single species control group—Days 20, 40, 60, and 100; and *F. hepatica* single species control group—Days 40, 45, 50, 60, and 100.

The timing of the infestations in Sequence III was such that the acute phases

of the infestations coincided. Two metacercariae of *F. hepatica* were given to each of 40 mice of the concurrent infestation group and 28 mice of the *F. hepatica* single species control group on Day 0. Ten cysticercoids of *H. microstoma* were given to each mouse of the concurrent infestation group and 18 mice of the *H. microstoma* single species control group on Day 15. One mouse from each group was killed to obtain tissues for histologic preparations on the days indicated: concurrent infestation group—Days 15, 20, 25, 30, 40, 45, 50, 60, 70, 80, and 100; *F. hepatica* single species control group—Days 20, 25, 35, and 100; and *H. microstoma* single species control group—Days 20, 30, 40, and 100.

The tissue for histologic studies was prepared for microscopic examination using a microtome–cryostat as described by Gleason (1971).

RESULTS

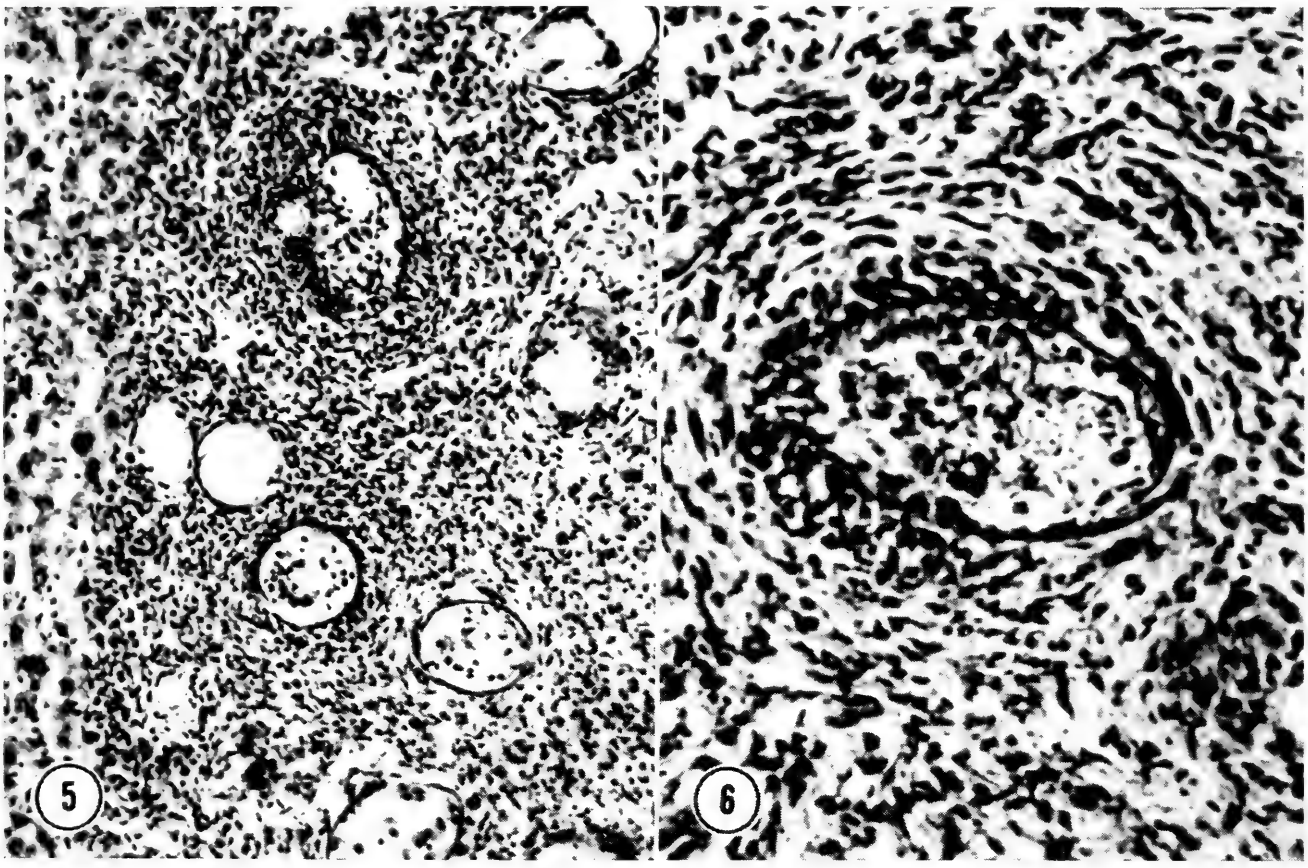
The pathologies in the livers of the *F. hepatica* and *H. microstoma* control mice in the 3 experiments were similar to those described previously for single species infestations resulting from the same infesting doses (Lang 1966, Gleason 1971).

In Sequence I, the mice of the concurrent infestation group were entering the chronic phase of the infestation with *F. hepatica* at the time the *H. microstoma* were given and the pathology in the liver was in the process of healing. The worm burrows were marked by heavy infiltrations of neutrophils and macrophages and the generalized necrosis could be distinguished by the concentration of lymphocytes in addition to the neutrophils and macrophages. The acute phase of the infestation with *H. microstoma*, 6 to 20 days after infestation, occurred 43 to 57 days after the infestation with *F. hepatica*. At that time, focal lesions from the infestation with *H. microstoma* could be clearly distinguished from pathology from the *F. hepatica* infestation by the predominance of neutrophils in the lesions, even though lymphocytes remained prevalent in the sinusoids of the liver.

In addition to the pathology normally observed in single species infestations with these species of worms, 2 types of tissue damage were observed in Sequence I. One pathology observed only in the mice of the concurrent infestation group was the reinstatement of the generalized necrosis characteristic of the acute phase of the infestation with *F. hepatica*. Small areas of the liver were first observed to be affected on Day 60. As the time of the concurrent infestation lengthened, more of the liver was involved, until as much as 50 percent of the organ was necrotic on Day 100. That necrosis was associated with accumulations of lymphocytes in the liver parenchyma and the periphery of the necrotic zone (Fig. 1). Neutrophils were the most prevalent cells within the necrotic areas.

A second type of pathology associated with the concurrent infestation was the presence of eggs of *F. hepatica* in the tissue of the mouse. At Day 50, eggs were first observed in intimate contact with the tissue of the common bile duct in areas where the epithelial lining had been sloughed off (Fig. 2). By Day 70, eggs were in the tissue of the wall of the common bile duct in these exposed areas (Fig. 3). At Day 80, eggs were observed in the tissues of the wall of the common bile duct, the wall of the cystic duct, the gall bladder, and in the liver itself (Figs. 4, 5). Later, eggs were observed in pancreatic ducts, lobular bile ducts, throughout the liver tissue, and some were encapsulated in the peritoneal cavity. The eggs had various degrees of cellular reactions around them. The infiltrating cells were a mixture of neutrophils (the dominant cell type), eosinophils, lymphocytes, and macrophages (Fig. 6).

In Sequence II, mice of the concurrent infestation group were entering the chronic phase of the infestation with *H. microstoma* at the time *F. hepatica* were given. At that time, focal lesions were common in the parenchyma of the liver, and leukocytes (predominantly neutrophils) were abundant in the sinusoids. Those conditions did not affect the liver migration of the *F. hepatica* and there was no reaction around the juvenile flukes. The onset of general-



FIGS. 5, 6. Pathology in mice resulting from concurrent infestations with *Fasciola hepatica* and *Hymenolepis microstoma*. Fig. 5. Eggs of *F. hepatica* in a large pocket in the tissue of the liver, Day 80. ×140. Fig. 6. Egg of *F. hepatica* in the wall of the common bile duct on Day 80. Note the concentric whorls of leukocytes around the egg. ×360.

ized necrosis in the livers of the mice of the concurrent infestation group was similar to that observed in the *F. hepatica* control mice. There was, however, a difference in the longevity of the necrosis. The generalized necrosis was present in the livers of the mice of the concurrent infestation group on Day 90, 90 days after infestation with *F. hepatica*. The extension of generalized necrosis occurred even though the flukes had entered the common bile duct at the normal time for mice, 30 to 35 days after infestation.

In Sequence III, the infestations with *F. hepatica* and *H. microstoma* were administered so that the midacute phase of each infestation occurred on Day 25. At that time, numerous neutrophils and lymphocytes were present in the sinusoids of the liver and generalized necrosis was widespread. The number of leukocytes appeared to be, at a minimum, totally additive in response to the acute phase of each infestation. *F. hepatica* were observed in the common bile duct of the mice of the concurrent infestation group at that time, 5–10 days earlier than in mice of the *F. hepatica* control group.

Eggs of *F. hepatica* were observed in the walls of lobular bile ducts and in the liver tissue of 1 mouse on Day 50. It was the only mouse in Sequence III in which that condition was observed, and the occurrence must have been irregular. The eggs were surrounded with infiltrating leukocytes in the same manner as previously described for Sequence I.

DISCUSSION

As expected, pathologies normally observed in infestations of mice with *F. hepatica* and *H. microstoma* were observed in concurrent infestations with those parasites during the present experiments. Individual pathologies occurred irrespective of the sequence or timing of the infestations as

independent functions of their initiators. Only in Sequence III was there any indication that there might be a synergistic effect of the 2 infestations. In that case, the enormous increase in the number of leukocytes in the sinusoids of the liver in response to the synchronized acute phases may have been more than additive, but quantitative measurement of a response of that nature is difficult.

The pathologies observed in concurrent infestations but not in single species control mice may have been related to a partial or complete blockage of the bile flow resulting from the worm mass of the combined infestations in the common bile duct. Gleason (1974) reported that when an infestation with *H. microstoma* was imposed upon a patent infestation with *F. hepatica*, there was a shift of attachment sites of the cestodes into the proximal region of the common bile duct. That shift brought the scoleces of the cestodes and much of the strobila into intimate contact with the *F. hepatica* present in that region.

The reinstatement or prolongation of generalized necrosis in livers of mice of the concurrent infestation groups of Sequence I and II was not as widespread as during the acute phase of an initial infestation with *F. hepatica*. However, it did affect large areas of the liver. It is probable that this pathology can be attributed to reduction or stoppage of bile flow. Under those conditions, antigenic material present in bile from adult *F. hepatica* in the lumen of the common bile duct would back up into the liver through the intrahepatic ducts. In the liver, the antigenic material would come into contact with sensitized lymphocytes that remain in the liver (Lang 1967). The reaction between the antigenic material and the sensitized lymphocytes would then induce the generalized necrosis.

The second pathology present in livers of mice of the concurrent infestation group of Sequence I and one mouse of Sequence III, but not in the single species control mice, was the presence of eggs of *F. hepatica* in the tissue. That condition could have been caused by the accumulation of eggs in the proximal region of the common bile duct due to a decreased flow of bile. Once trapped in the proximal region, the eggs became entangled in the serous exudate at breaks in the epithelial lining of the common bile duct and were later forced into the tissues through a combination of fluid pressure and mechanical pressure by the worms.

Urquhart (1956) found eggs of *F. hepatica* in the hepatic and biliary tissues of rabbits. He postulated that the eggs entered the tissues through breaks in the epithelial lining of the intrahepatic ducts caused by adult flukes. The eggs were found singly and in clusters, much the same as observed during the present experiments. In the rabbit, however, adult *F. hepatica* were in the intrahepatic bile ducts, while in the mouse the flukes were in the proximal regions of the common bile duct. Thus, in rabbits, more eggs were found in the hepatic tissues. After the eggs entered the tissue, the reaction of the mouse to the eggs was similar to that described by Urquhart (1956) for rabbits. The eggs were invaded by neutrophils, eosinophils, and macrophages. Later, a specific type of granuloma was produced when the eggs were surrounded by concentric whorls of neutrophils, macrophages, and fibroblasts.

The failure to find eggs of *F. hepatica* in tissues of *F. hepatica* control mice, mice of the concurrent infestation in Sequence II, and rarely in mice of the concurrent infestation in Sequence III, would indicate that the timing and sequence of infestation used in Sequence I provided the conditions necessary to force the eggs into the tissues. This probably is correlated with the findings of Gleason (1974) that there was no proximal shift in the attachment sites of *H. microstoma* when an infestation with *F. hepatica* was imposed upon a patent infestation with *H. microstoma* or when the infestations were synchronized so that the midacute phase of each infestation occurred simultaneously.

LITERATURE CITED

GLEASON, L. N. 1971. The responses of the white mouse to a primary infection with

Hymenolepis microstoma. J. Elisha Mitchell Sci. Soc. 87:11–17.

———. 1974. New data on the interactions between the bile duct dwellers, *Fasciola hepatica* (Trematoda) and *Hymenolepis microstoma* (Cestoda), in mice. J. Elisha Mitchell Sci. Soc. 90:58–63.

LANG, B. Z. 1966. Host-parasite relationships of *Fasciola hepatica* in the white mouse. I. Response to a primary infection. J. Elisha Mitchell Sci. Soc. 82:195–203.

———. 1967. Host-parasite relationships of *Fasciola hepatica* in the white mouse. II. Studies on acquired immunity. J. Parasit. 53: 21–30.

LITCHFORD, R. G. 1963. Observations on *Hymenolepis microstoma* in three laboratory hosts: *Mesocricetus auratus, Mus musculus* and *Rattus norvegicus*. J. Parasit. 49:403–410.

SIMPSON, G. F., AND L. N. GLEASON. 1975. Lesion formation in the livers of mice caused by metabolic products of *Hymenolepis microstoma*. J. Parasit. 61:152–154.

URQUHART, G. M. 1956. The pathology of experimental fascioliasis in the rabbit. J. Path. Bact. 71:301–311.

Threatened Fishes of Daniel Boone National Forest, Kentucky

Branley A. Branson
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Long-term field collecting, surveys of the literature, and museum holdings indicate that at least 21 fish species within the confines of Daniel Boone National Forest, Kentucky, are threatened by various human undertakings, principally surface mining. Of those, 13 species are judged as rare or endangered. The most critical areas lie in the upper Kentucky River drainage, lesser impacts being felt in the Cumberland and Licking river systems.

Introduction

During the last decade, there has been a concerted attempt to understand native American animals that are becoming rare and endangered, particularly fishes. The Endangered Species Preservation Act of 1966, following extensive clamoring by various scientific societies, gave impetus to the preservation movement. Following that, the U.S. Department of the Interior (1968) printed the so-called "Red-Book of Rare and Endangered Fish and Wildlife of the United States" and Miller (1972) presented a list of the threatened fishes of the entire United States. However, the information in both works concerning the fishes of Kentucky is sparse, indeed, and has led to the conclusion that dependence upon such works with regard to localized fish faunas, such as that of the Daniel Boone National Forest in Kentucky, can be highly misleading. As suggested by Robinson et al. (1974), a fish species may be seriously threatened in one part of its total range and yet be comparatively safe elsewhere. Not only is this true from a broader geographic vantage, it is also true from one river system to another. Thus, among the more than 140 fish species of the Daniel Boone National Forest, only 2 appear in the Red Book. One, *Lagochila lacera*, the harelip sucker, is doubtless extinct, and the second, *Acipenser fulvescens*, the lake sturgeon, is designated as threatened.

Because of the points made above, I deemed it necessary to discuss the threatened fishes of the Daniel Boone National Forest. This article is extracted from a longer report prepared for the U.S. Forest Service. The results are supported by literature records, extensive field work in eastern Kentucky, and museum holdings of other institutions as well as those of Eastern Kentucky University.

In the annotated list which follows, the scientific and common names follow Bailey et al. (1970). The judgement terms that describe the status of each species in the Daniel Boone National Forest are those of Miller (1972) except threatened, which is used in the context explained below:

Endangered: facing extinction; continued survival unlikely without special protective measures.

Rare: not immediately faced with extinction, but present in such small numbers or in restricted to highly specialized habitats that could vanish. Requires careful watching.

Threatened: massive and active habitat degradation occurring across a broad spectrum of the range.

It must be stressed here that these designations apply only to fishes within the confines of the Daniel Boone National Forest and not the entire Commonwealth of Kentucky.

Annotated List of Threatened Fishes

Within the confines of the Daniel Boone National Forest, 21 species of fishes are judged to suffer at one level or another by way of habitat deterioration. Of those, 9 are considered rare and 4 endangered; the remaining 8 are listed as threatened.

Polyodon spathula. Paddlefish.—Kentucky

distribution: formerly abundant in the main stems and principal tributaries to the Ohio and Mississippi rivers, principally in the lower ends of the Cumberland, Kentucky, Licking, and Big Sandy rivers.

Remarks: Professor A. L. Whitt (pers. comm.) has recently observed specimens at Kentucky Lake near the dam, and I saw a living adult at Lake Cumberland during April 1975. Several specimens, 25–38 cm, were secured from lock chambers at Cannelton, Uniontown, Newburgh, and McAlpine locks and dams during 1972–1974, indicating successful reproduction in the Ohio River (Dr. Louis A. Krumholz, pers. comm.).

Status: threatened.

Acipenser fulvescens. Lake sturgeon.—Kentucky distribution: before 1900, the lake sturgeon was common in the Ohio River, in portions of the Cumberland River below the falls, and abundant in the lower Licking River. Only a single Kentucky record (1954) since the early 1900's.

Remarks: most of the large runs within the state have been decimated severely, but still persists in the Ohio and Tennessee rivers (Clay 1975).

Status: endangered.

Scaphirhynchus platorynchus. Shovelnose sturgeon.—Kentucky distribution: the only verified record is from the Licking River at Farmer (Welter 1938) with regard to the Daniel Boone National Forest. However, Krumholz et al. (1962) reported one taken in August 1959 in a hoopnet set in the lower reaches of the Ohio River near Mound City, Illinois. Charles (1962) reported specimens taken by commercial fishermen throughout the Kentucky waters of the Ohio River.

Remarks: probably extinct in Kentucky waters other than the Ohio River.

Status: endangered.

Amia calva. Bowfin.—Kentucky distribution: principally in the southwestern lowlands and in the Ohio River as far eastward as Cincinnati.

Remarks: the only specimens from Daniel Boone National Forest waters came from backwater pools of Tygarts Creek, Carter County. The main reason for this species rarity in national forest waters probably is the lack of suitable habitat.

Status: rare.

Clinostomus funduloides. Rosyside dace.—Kentucky distribution: published records from the Big Sandy and Little Sandy rivers, Tygarts and Kinniconick creeks. Eastern Kentucky University has specimens from the Little Licking River.

Remarks: both species of *Clinostomus* that occur in Kentucky are considered as specialized relics (Clay 1975) that occupy marginal habitats. Since the distribution of the species under consideration barely includes Daniel Boone National Forest streams, the species is judged as rare.

Status: rare.

Hybognathus nuchalis. Silver minnow.—Kentucky distribution: Lower Ohio River drainage and western portion of the state.

Remarks: earlier collectors (Woolman 1892) reported the species from more easterly streams, but the only recent record from the Daniel Boone National Forest is that of Branson and Batch (1972a), a single specimen from Clear Creek near Wildie, Rockcastle County. The fish has nearly disappeared from the Upper Ohio River basin (Clay 1975, Trautman 1957) as the result of massive siltation.

Status: rare.

Hybopsis aestivalis. Speckled chub.—Kentucky distribution: lower portions of all main rivers.

Remarks: threatened in the uplands by dam construction and silt and acid from strip mines. Extirpated from the Red Bird River and greatly reduced in numbers in the rest of the upper Kentucky River basin.

Status: rare.

Notropis ariommus. Popeye shiner.—Kentucky distribution: upper Green, Cumber-

land, Laurel, Rockcastle, and Kentucky rivers.

Remarks: now very rare in most of the upper Kentucky River system. Extirpated from Red Bird River and Goose Creek by strip mining, but still relatively abundant in Greasy Creek, although that stream's drainage is now involved in mining operations.

Status: threatened.

Notropis telescopus. Telescope shiner.—Kentucky distribution: known only from Crocus and Rock creeks, both in the Cumberland River system.

Remarks: because this species requires clear, headwater streams, its habitat is now strongly threatened by surface mining.

Status: rare.

Lagochila lacera. Harelip sucker.—Kentucky distribution: apparently once confined to the Cumberland River system (Woolman 1892).

Remarks: since the species has not been reported during the last 75 years, it is considered extinct.

Status: extinct.

Stizostedion vitreum. Walleye.—Kentucky distribution: in most of the larger streams before the turn of the century (Evermann 1918; Carter and Jones 1969; Small 1970, unpublished master's thesis, University of Kentucky, Lexington, Kentucky; Welter 1938; Woolman 1892).

Remarks: there has been a dramatic reduction in populations of the walleye in the Daniel Boone National Forest (Clay 1975). The Cave Run hatchery is attempting to rear walleyes artificially for repopulating Kentucky waters.

Status: rare (threatened?).

Percina burtoni. Blotchside logperch.—Kentucky distribution: formerly abundant in the Little South Fork of the Cumberland River in Wayne and McCreary counties (pers. comm., Dr. David Etnier, University of Tennessee, Knoxville, Tennessee).

Remarks: since there are no recent records of the species from Kentucky, and since the headwater streams of the Cumberland River are being assaulted by strip mining, the species must be judged endangered.

Status: endangered.

Percina evides. Gilt darter.—Kentucky distribution: Big Sandy, Green, Licking, and Kentucky river systems.

Remarks: although comparatively safe in parts of its total range, the gilt darter has nearly disappeared from Ohio and Indiana (Trautman 1957), principally because of increased siltation and construction of dams. Extensive collecting has not disclosed specimens from the upper Cumberland River and only rarely is the species encountered in the Licking and upper Kentucky river systems.

Status: rare.

Percina cymatotaenia. Bluestripe darter.—Kentucky distribution: Big Sandy, Green, Licking, and Kentucky river drainages, and Station Camp (Jackson County) and Obion (Hickman County) creeks.

Remarks: the epithet used above is utilized for this species pending completion of Mr. Bruce Thompson's research at Tulane University. With the exception of habitats in the Red River of Powell and Wolfe counties, and in Station Camp Creek, much of this species range in eastern Kentucky is being heavily influenced by strip mining.

Status: threatened.

Ammocrypta pellucida. Eastern sand darter.—Kentucky distribution: originally from the sandy portions of all principal drainages from the mouth of the Cumberland River eastward (Clay 1975).

Remarks: Evermann (1918) reported specimens from the upper Cumberland River from a site now inundated by Lake Cumberland; sand darters have not been reported from that drainage since. Before

impoundment of the Licking and Kentucky rivers, sand darters were abundant in both streams; now the species is very rare. Strip mining is also destroying many habitats, although sand darters are still present in downstream sections of the Red River in Powell and Clark counties.

Status: threatened.

Etheostoma rufilineatum. Redline darter.—Kentucky distribution: Clark's River (Tennessee River system) and portions of the Cumberland River drainage. In eastern Kentucky, the species has been reported from Cumberland, Pulaski, and Wayne counties only (Zorach 1970).

Remarks: I also have specimens from Buck Creek (Kentucky State Highway 192 crossing)in Pulaski County. Other than that, all records lie peripheral to the forest. Although apparently healthy elsewhere, the redline darter is scarce or rare in Daniel Boone National Forest streams.

Status: rare.

Etheostoma tippecanoe. Tippecanoe darter.—Kentucky distribution: middle portions of the Kentucky and Licking river drainages.

Remarks: populations in Red Bird River and South Fork of the Kentucky River have markedly declined following strip mining in those drainages.

Status: threatened.

Etheostoma obeyense. Barcheek darter.—Kentucky distribution: Cumberland and Green river systems.

Remarks: a peripheral species which barely enters forest waters.

Status: rare.

Etheostoma cinereum. Ashy darter.—Kentucky distribution: known only from the Little South Fork of the Cumberland River, Rock Creek in McCreary County (Kirsch 1892) and Buck Creek near Highway 80, Pulaski County (Clay 1975) and the Rockcastle River below the mouth of Buck Creek.

Remarks: the rarest darter in Kentucky; only 3 specimens have been collected since 1892. The habitat area is now under siege by strip mining.

Status: threatened.

Etheostoma atripinne. Cumberland snubnose darter.—Kentucky distribution: Cumberland River system.

Remarks: since much of the Cumberland River basin is being influenced by strip mining, there has been a marked decrease in the abundance of snubnose darters.

Status: threatened.

Etheostoma sagitta. Arrow darter.—Kentucky distribution: upper Cumberland and upper Kentucky river basins.

Remarks: there are 2 subspecies of this darter in Daniel Boone National Forest waters, *E. sagitta sagitta* in the headwaters of the Cumberland River (Bailey 1948), type locality in Wolf Creek near Pleasant View, Whitley County, Kentucky, and *E. sagitta spilotum*, type locality at Travelers Rest, Owsley County, Kentucky, in the upper Kentucky River basin (Kuehne and Bailey 1961). In addition to the upper Kentucky River records of Kuehne and Bailey, Gilbert (1887), and Woolman (1892), I have specimens from Red Bird River, Middle and South forks of the Kentucky River in Breathitt and Leslie counties, all heavily afflicted by strip mining and acid mine drainage (see also Branson and Batch 1972b). The fish's habitat streams in the upper Cumberland are also greatly damaged by surface mining.

Status: threatened.

DISCUSSION

At the present time, approximately 140 fish species, distributed through 22 families and 54 genera, are known from the Daniel Boone National Forest, Kentucky, and an additional 16 species are "possibles" since they have been collected from streams near the forest boundaries. Twenty-one species are judged as threatened. Exclud-

ing the extinct harelip sucker, 3 species are endangered and 10 are rare; the remainder are in the threatened category. Protective measures are indicated, if this appreciable segment of the Kentucky fish fauna is to survive within the forest.

The principal habitat degraders in this area are municipal sewage pollution, highway construction, improper farming practices, channel straightening, strip mine silt and acid mine drainage, deforestation, stone quarrying operations, and construction of many dams. In many areas, the effects have been tragically destructive to fish faunas. Because of these interacting forces, the Daniel Boone National Forest stands a good chance of having a sizeable segment of its fish fauna extirpated. The first step to prevent such a catastrophe is recognition of the fact that various segments of the fauna and some individual species are threatened. Logically, this type of recognition should be followed by an evaluation of local faunas and by legislative action when protective measures are deemed necessary.

LITERATURE CITED

BAILEY, R. M. 1948. Status, relationships, and characters of the percid fish, *Poecilichthys sagitta* Jordan and Swain. Copeia 1948:77–85.

BAILEY, R. M., J. M. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSAY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of the common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. 6:1–149.

BRANSON, B. A., AND D. L. BATCH. 1972a. Fishes of Clear Creek, tributary to Rockcastle River, Kentucky. Trans. Ky. Acad. Sci. 33: 33–35.

————, AND ————. 1972b. Effects of strip mining on small-stream fishes in east-central Kentucky. Proc. Biol. Soc. Wash. 84: 507–517.

CARTER, J. P., AND A. R. JONES. 1966. Inventory and classification of streams in the Upper Cumberland River drainage of Kentucky. Ky. Fish. Bull. 52:1–70.

CHARLES, J. R. 1962. Commercial fishing activities in the Kentucky waters of the Ohio River. Pp. 103 ff. *In* Aquatic-life resources of the Ohio River. Ohio River Valley Water Sanit. Comm., Cincinnati, Ohio 218 pp.

CLAY, W. M. 1975. The Fishes of Kentucky. Ky. Dept. Fish Wildl. Res. Frankfort, Ky. 416 pp.

EVERMANN, B. W. 1918. The fishes of Kentucky and Tennessee: a distributional catalogue of the known species. Bur. Fish. Bull. 858:295–368.

GILBERT, C. H. 1887. Descriptions of new and little known etheostomoids. Proc. U.S. Natl. Mus. 10:47–64.

KIRSCH, P. H. 1892. Notes on the streams and fishes of Clinton County, Kentucky, with description of a new darter. Bull. U.S. Fish. Comm. (1890) 10:289–292.

KRUMHOLZ, L. A., J. R. CHARLES, AND W. L. MINCKLEY. 1962. The fish population of the Ohio River. Pp. 49 ff. *In* Aquatic-life resources of the Ohio River. Ohio River Valley Water Sanit. Comm., Cincinnati, Ohio 218 pp.

KUEHNE, R. A., AND R. M. BAILEY. 1961. Stream capture and the distribution of the percid fish *Etheostoma sagitta*, with geologic and taxonomic considerations. Copeia 1961:1–8.

MILLER, R. R. 1972. Threatened fishes of the United States. Trans. Amer. Fish. Soc. 101: 239–252.

ROBINSON, H. W., G. A. MOORE, AND R. J. MILLER. 1974. Threatened fishes of Oklahoma. Proc. Okla. Acad. Sci. 54:139–146.

TRAUTMAN, M. B. 1957. The Fishes of Ohio. Ohio State Univ. Press, Columbus, Ohio. 683 pp.

U.S. DEPARTMENT OF THE INTERIOR. 1968. Red Book of Rare and Endangered Fish and Wildlife of the United States. Washington, D.C.

WELTER, W. A. 1938. A list of the fishes of the Licking River drainage. Copeia 1938:64–68.

WOOLMAN, A. J. 1892. Report of an examination of the rivers of Kentucky, with lists of the fishes obtained. Bull. U.S. Fish. Comm. (1890) 10:249–288.

ZORACH, T. 1970. The systematics of the percid fish *Etheostoma rufilineatum* (Cope). Amer. Midl. Nat. 84:208–225.

Natural Bridges of Southern Christian County, Kentucky

James X. Corgan and John T. Parks
Austin Peay State University, Clarksville, Tennessee 37040

Abstract

This report describes and illustrates the 2 westernmost natural bridges in Kentucky: Noah Creek Natural Bridge and Fort Campbell Arch. Both are developed in limestones of Mississippian Age and both occur on the Fort Campbell Military Reservation. The 2 new discoveries bring to 20 the total number of bridges and arches described from Kentucky.

Introduction

Two previously undescribed natural bridges occur in the north-central part of the Fort Campbell Military Reservation in southern Christian County, Kentucky (Fig. 1). A review of the literature suggests that, with these discoveries, a total of 20 natural bridges have now been formally described from Kentucky (e.g. Cleland 1905, 1910; McFarlan 1943, 1954, 1958; McGrain 1966a, 1966b; Miller 1898; and Scott and Belknap 1926). Although natural bridges and arches are fairly common in parts of eastern and central Kentucky, they apparently are rare in Mississippian age carbonate rocks of the south-central part of the state.

Acknowledgments

We are indebted to Henry A. Post and James E. Price of the Environmental Office, Facility Engineers, Fort Campbell, Kentucky. They aided in field measurements and facilitated access to remote parts of the post.

Noah Creek Natural Bridge

Noah Creek Natural Bridge (Fig. 2) is part of an unusual complex of topographic features along Noah Creek in the north-central part of the Fort Campbell Military Reservation. Fort Campbell authorities have recognized the extraordinary beauty of this area by setting it aside for nonmilitary use. It is officially designated the Noah Creek Recreation Area.

Within that recreation area, the natural bridge is the most distinctive topographic feature. Just upstream from the bridge, Noah Creek begins to flow along a near vertical cliff that contains Noah Cave. In between the natural bridge and the cave, Noah Creek disappears. Its waters pass into subsurface drainage. The point of transition from surface to subsurface drainage depends on the volume of water in the creek. During low flow, the stream disappears into solution widened bedding planes beneath the bridge. At high water, the stream moves further down its channel. At that stage, most of the water enters the cave where it cascades into subterranean drainage. The combination of a cave, a disappearing stream, a vertical cliff, and a natural bridge forms a unique and aesthetically pleasing cluster of landscape elements.

All parts of this landscape complex are clearly interrelated. On the south, the bridge merges with the cliff which rises some 26 feet (7.9 m) above the base of the bridge. Most of the higher strata in the cliff have fallen away from the bridge roof, leaving an irregular, brush covered arch. At its highest, the bridge is at least 9 feet (2.7 m) below the crest of the cliff.

On the north side, the bridge blends into alluvial deposits of Noah Creek. A small, brush covered, rocky step, about 1.5 feet (46 cm) high, separates the bridge from the alluvium. Because of dense vegetation it is difficult to measure accurately the external length of the bridge. At a maximum, the bridge extends some 20 to 22 feet (6.1–6.7 m) from the cliff. The northern bridge pillar is thin, less than 10 feet (3 m) in thickness.

In the east-west direction the bridge

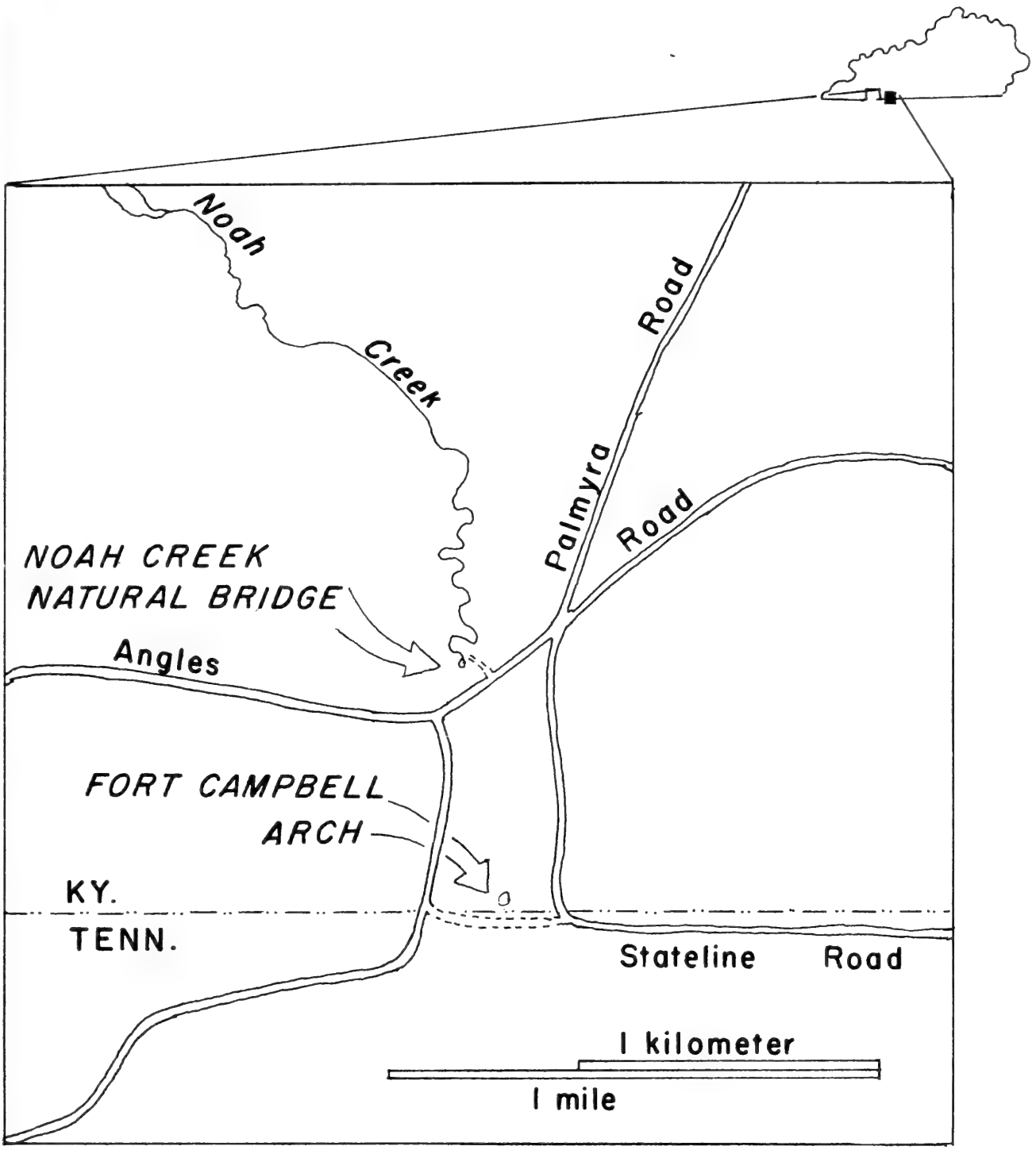


FIG. 1. Locations of Noah Creek Natural Bridge and Fort Campbell Arch.

rises above Noah Creek in a sheer wall. It is tunnel shaped and extremely angular. Internal height varies from season to season, depending upon sediment fill in the creek channel. In the spring of 1976, the maximum internal height was about 8.5 feet (2.6 m). The maximum span is presently about 12.3 feet (3.7 m) and the width down the middle is some 31.5 feet (9.6 m).

From the shape of the bridge and from the topographic setting, it is obvious that Noah Creek Natural Bridge was once part of the adjacent cave. The bridge now stands some 76 feet (23.2 m) from the cave mouth. The separation has been produced by collapse of the intervening section of cave. Collapse was controlled by solution along 2 intersecting sets of vertical joints.

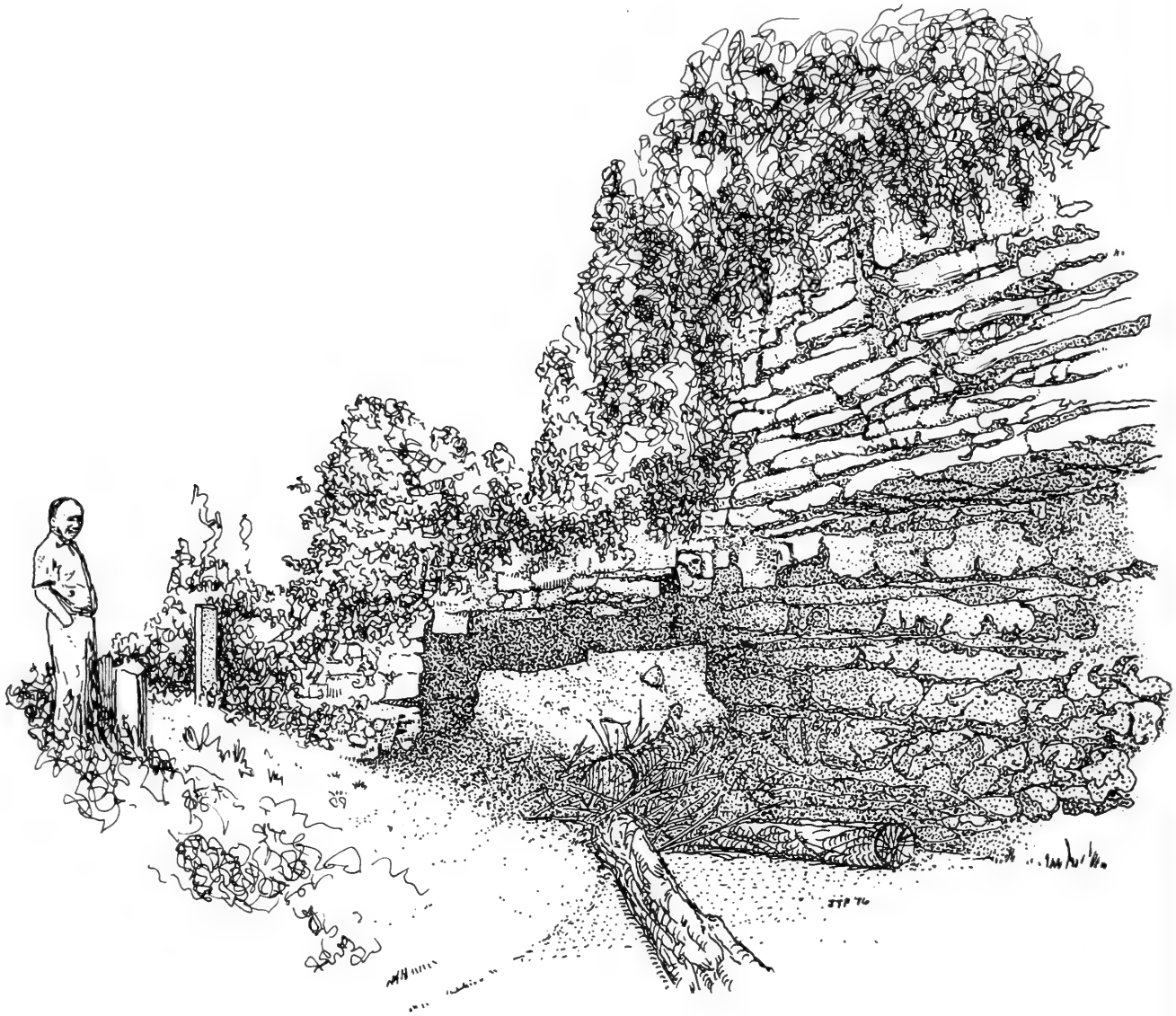


FIG. 2. Noah Creek Natural Bridge, looking east with the north pillar on the left.

The dominant joint set runs parallel to the cliff and also appears to parallel the general trend of Noah Cave. That joint set rather consistently strikes N85W. Collapse in that orientation established the north-south limits of the bridge. A second set of less well-developed joints strikes roughly N10E to N25E. That set shapes the east-west limits of the bridge. Collapse along that set has separated the bridge from the cave. The interaction of 2 sets of nearly vertical joints accounts for the boxy angularity of the bridge.

While Noah Creek Natural Bridge is now mechanically sound and should continue to exist for many decades, further joint controlled collapse can be anticipated. Continued collapse will, ultimately, destroy the bridge. Both the creation and the eventual destruction of the bridge reflect the relative resistance to erosion of rocks that form the bridge and the cliff. Klemic (1966) mapped the geology of the region. His map identifies the cliff forming and bridge forming rocks as flat lying beds within the St. Louis Limestone of Mississippian age.

Stratigraphically, the bridge forming rocks and rocks that form the crest of the cliff are near the contact between the St. Louis and the overlying St. Genevieve limestones. At that contact, dolomite rich and silt rich beds of the upper St. Louis are overlain by pure limestones of the St. Genevieve. Within the Fort Campbell region, those dolomitic and silty beds vary in thickness, reaching at least 10 to 12 feet (3–3.7

m) in the Noah Creek area. They are underlain by purer limestones within the St. Louis. Both mechanically and chemically, the uppermost St. Louis is especially resistant to erosion. It is the lithologic character that creates the top of Noah Creek Natural Bridge and the crest of the adjacent cliff.

FORT CAMPBELL ARCH

About a half mile (800 m) due south of Noah Creek Natural Bridge and about 50 feet (15.3 m) north of the Tennessee State Line lies the southernmost natural bridge in Kentucky (Fig. 1). This small bridge, here called Fort Campbell Arch, stands about 12 feet (3.7 m) high, with a 10-foot (3 m) clearance under the arch. It occurs in the same stratigraphic position as Noah Creek Natural Bridge but in other ways the smaller bridge is quite different.

Fort Campbell Arch spans a sharply defined trough-like depression which trends about N70W and has a near vertical north wall. The bridge is near the west end of the hollow which remains well defined for about 40 feet (12.2 m) east and 15 feet (4.6 m) to the west. In the vicinity of the bridge, the depression has a width of 7–10 feet (2.1–3 m) and an average depth of about 12 feet (3.7 m). The base of the trough, which is also the base of the bridge, is a nearly horizontal bedding plane within the St. Louis Limestone. Weathering has enlarged this plane to permit a free flow of water. Drainage is to the south.

Proportions of Fort Campbell Arch are shown in Fig. 3. The upper portion of the bridge is a dolomitic unit near the top of the St. Louis Limestone. Underlying horizons are purer limestone and, thus, more soluble. Existence of the bridge can apparently be attributed to 2 factors, solution controlled enlargement of a vertical joint and low solubility of the upper horizon.

While Noah Creek Natural Bridge has been set aside for recreational use, Fort Campbell Arch is currently left in its natural state. This seems to be a wise decision for the arch is too small to permit access by a large number of people.

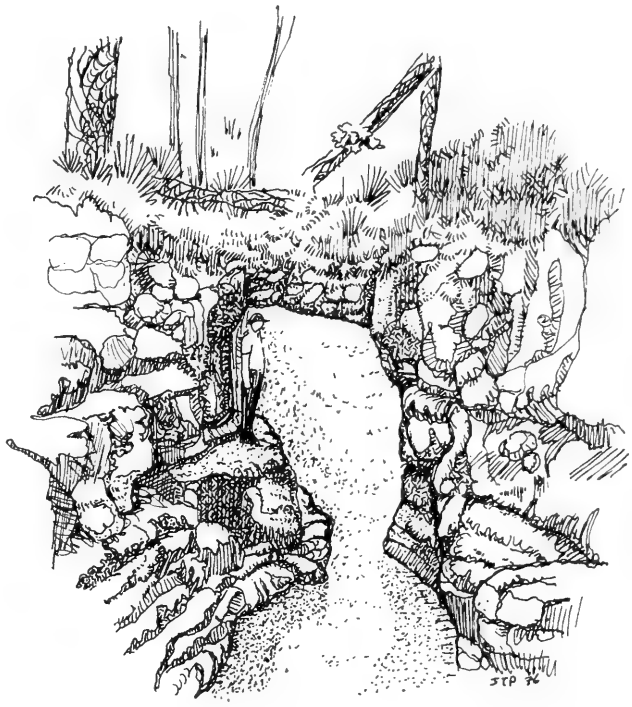


FIG. 3. Fort Campbell Arch. A dense plant growth makes the deck of this bridge appear thicker than it actually is.

SUMMARY AND CONCLUSIONS

Two natural bridges are known to exist in southern Christian County, Kentucky. They are here termed Noah Creek Natural Bridge and Fort Campbell Arch, with the former being larger.

Noah Creek Natural Bridge was created by 2 interacting processes: joint controlled cave collapse and differential solution of dissimilar carbonate rock strata. Differential solubility was also an important factor in creating Fort Campbell Arch. At that site, solution controlled widening of a joint is the most evident factor in bridge formation.

Noah Creek Natural Bridge and related features are large enough for intensive public use. This area is now officially set aside for recreational purposes. Fort Campbell Arch is too small and too fragile to permit access by a large number of people. Therefore, it should be left in its natural state.

Both bridges occur in the upper part of the St. Louis Limestone formation, close to the contact with the overlying and more soluble St. Genevieve Limestone. Both

bridges involve the same thin zone of relatively insoluble rocks. The occurrence of 2 bridges in this stratigraphic setting suggest that throughout south-central Kentucky and adjacent Tennessee, natural bridges should be anticipated in the upper St. Louis Limestone wherever similar stratigraphic conditions exist.

LITERATURE CITED

CLELAND, H. F. 1905. The formation of natural bridges. Amer. J. Sci. (4) 20:119–124.

———. 1910. North American natural bridges, with a discussion of their origin. Bull. Geol. Soc. Amer. 21:313–338; 765–776.

KLEMIC, H. 1966. Geologic map of the Herndon Quadrangle, Kentucky–Tennessee. U.S. Geol. Surv. Map GQ–572.

MCFARLAN, A. C. 1943. Geology of Kentucky. Univ. Kentucky Press, Lexington, Ky. 531 pp.

———. 1954. Geology of the Natural Bridge State Park area. Ky. Geol. Surv. (9) Spec. Publ. 10:1–31.

———. 1958. Behind the scenery in Kentucky. Ky. Geol. Surv. (9) Spec. Publ. 10: 1–144.

MCGRAIN, P. 1966a. Geology of The Cumberland Falls State Park area. Ky. Geol. Surv. (10) Spec. Publ. 11:1–33.

———. 1966b. Geology of the Carter and Cascade Caves area. Second Edition. Kentucky Geol. Survey (10) Spec. Publ. 12:1–32.

MILLER, A. M. 1898. Natural arches of Kentucky. Science 7:845–846.

SCOTT, I. D., AND R. L. BELKNAP. 1926. The Creelsboro Natural Bridge of Russel County, Kentucky. Pap. Mich. Acad. Sci. Arts Lett. 7:125–133.

Use of Woodchuck Burrows by Woodchucks and Other Mammals

L. L. Schmeltz and John O. Whitaker, Jr.
Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809

Abstract

Live traps were set in the entrances of 94 woodchuck burrows along a flood control dike in Vigo County, Indiana, in such a way as to capture large mammals inside the burrows. Besides 35 woodchucks, 20 opossums *Didelphis virginiana*, 19 cottontails *Sylvilagus floridanus*, 8 raccoons *Procyon lotor*, 1 red fox *Vulpes vulpes*, and 1 gray fox *Urocyon cinereoargenteus* were taken. Snap traps set in the same burrow entrances yielded 104 white-footed mice *Peromyscus leucopus*, 32 house mice *Mus musculus*, 10 short-tailed shrews *Blarina brevicauda*, and 2 each of the meadow jumping mouse *Zapus hudsonius*, the meadow vole *Microtus pennsylvanicus*, and the masked shrew *Sorex cinereus*.

Introduction

There is scattered information on the use of woodchuck burrows by mammals other than woodchucks. Hamilton (1934) indicated that rabbits, skunks, foxes, and weasels frequently use woodchuck burrows, and also related occasional use by chipmunks and house cats. Grizzell (1955), mentioned most of those species, and also opossums, raccoons, squirrels, ground squirrels, and some small mammals including *Mus musculus*, *Peromyscus leucopus*, *Microtus pennsylvanicus*, *M. pinetorum*, *Zapus hudsonius*, and *Blarina brevicauda*. To our knowledge, there has been no systematic effort to determine usage of woodchuck burrows by various species of mammals, and the purpose of this study was to determine such use.

Study Area

The study area was a grassy covered flood control levee along the west side of the Wabash River north of Terre Haute, Vigo County, Indiana. Major grasses present were *Bromus* sp. and fescue *Festuca* sp. Inside the levee (away from the river) the land consisted mostly of cornfields. Outside was about 50 percent cultivated land. Trees present were primarily silver maple *Acer saccharinum* and cottonwood *Populus deltoides*. The levee is about 8 km long, but the portion used for this study consisted of about 3,500 m. Levee maintenance included yearly burning, usually about 1 March.

Materials and Methods

A series of 94 woodchuck burrow openings that appeared to have been in recent use (as indicated by presence of cuttings, fresh dirt, odor, tracks) was studied along a section of dike. The dens were marked with numbered stakes. Large Tomahawk live traps baited with corn were used to sample the large mammals. A trap was placed with its door in the mouth of the burrow in such a way that it would be likely to capture an animal inside the burrow at the time the trap was set. Those traps were used at about 1–3 month intervals from October 1970 through April 1972. The mamals were toe clipped in a consecutively numbered series, sexed, weighed, and released at the point of capture. A card including the date of each capture, approximate age at first capture, weight in pounds, and the burrow number for each capture was made for each numbered animal. Later, 199 woodchucks were trapped with No. 2 steel and No. 220 conibear traps, or shot with a .22 caliber rifle, many of them beyond the limits of the trapping area.

Burrow use by small mammals was studied using 2 snapback mousetraps placed inside the entrance of each burrow during 5 different 2-day periods during the study. Unfortunately, no traps were used that would sample weasels or chipmunks.

TABLE 1.—USE OF WOODCHUCK BURROWS BY LARGE MAMMALS ON A FLOOD CONTROL LEVEE ALONG THE WABASH RIVER AT TERRE HAUTE, VIGO COUNTY, INDIANA

	Animals Taken		Captures and Recaptures	
	No.	%	No.	%
Woodchuck	35	42.1	74	57.4
Opossum	20	24.1	21	16.3
Cottontail	18	21.7	24	18.6
Raccoon	8	9.6	8	6.2
Gray Fox	1	1.2	1	0.8
Red Fox	1	1.2	1	0.8
	83	99.9	129	100.1

RESULTS AND DISCUSSION

Six species of large mammals were taken, including 129 total captures and recaptures of 83 individuals (Table 1). Mammals were caught at 62 of the 98 burrow entrances, thus 36 (36.7%) yielded no larger mammals. Thirty-five different woodchucks were taken a total of 74 times. This constituted 42.1 percent of all large mammals taken, and 57.4 percent of all captures and recaptures. Ten woodchucks were captured once and never seen again, while 6 others were taken once in the burrows and later in conibear traps in or near the study area. Those 6 were retaken 1 to 18 months after the first capture, an average of 1,456 m from the initial capture site (28 m to 3.6 km). The animal retaken after 18 months was 46 m from the original burrow. Two others were taken at sites about 2.4 km apart with short periods between recaptures, 27 and 24 days, respectively. Nineteen individuals accounted for the 39 recaptures. Six were taken twice, 9 were taken 3 times, 2 were taken 4 times, 1 was taken 5 times, and 1 was taken 6 times. Most were taken in different traps each time they were captured, except 1 was taken 3 times in the same trap, and 5 were taken twice in the same trap. One woodchuck, taken in a burrow on 16 October 1970 was retaken in a burrow 800 m away on 9 December 1970, and again in the first burrow on 29 March 1971. One individual was taken 5 times in 5 different burrows, all within a span of 18 days and 150 m. The one taken 7 times was in 5 different burrows within 185 m of one another over a 10-month period.

The latest fall date a woodchuck was taken was 9 December, although one individual appeared to be active throughout the winter of 1970–71, feeding on a patch of uncut corn near its burrow. Most dens were plugged during the winter. Early emergence was about 5 February, when 5 dens were found to have been recently reopened. By 25 February, a number of other dens had been reopened.

Eighteen cottontails, captured 24 times, comprised 21.7 percent of all mammals taken, and 18.6 percent of the total captures. Fifteen rabbits were captured once each, 1 was captured twice, 1 was taken 3 times, and 1 a total of 4 times. No rabbit was captured twice in the same burrow and only 2 burrows yielded more than 1 rabbit, 1 with 2 and 1 with 3. Cottontails used the burrows primarily during the colder months. There were 6 captures in October, 10 in November, 2 in December, and 4 in February.

Twenty opossums were taken. There was only 1 recapture seeming to indicate that the opossums did not live in the burrows, but simply visited them. Included were 7 males, all taken in fall, 6 females carrying young (May to July), and 7 other females.

Eight raccoons were taken, comprising 9.6 percent of all mammals taken. Five were females, 3 were males, and 4 were young. Raccoons used the burrows sporadically, with 1 capture each in May, July, and August, 3 in October, and 2 in November.

One red fox and 1 gray fox were taken in burrows during the study.

The most common small mammals in the general vicinity of the burrows were *Peromyscus leucopus*, *Microtus pennsylvanicus*, *Mus musculus*, and *Peromyscus maniculatus*. In the grassy areas of the burrows, *M. pennsylvanicus* was particularly abundant. However, that species seldom used the burrows (Table 2). The major user of the burrows among the small mammals was *Peromyscus leucopus*, 104 individuals being

TABLE 2.—USE OF WOODCHUCK BURROWS BY SMALL MAMMALS ON A FLOOD CONTROL LEVEE ALONG THE WABASH RIVER NEAR VIGO COUNTY, TERRE HAUTE, INDIANA. MAMMALS ARE INDICATED AS THE TOTAL NUMBER TAKEN AND THE NUMBER TAKEN PER 100 TRAPNIGHTS. THE NUMBER AND PERCENTAGE OF BURROWS IN WHICH EACH SPECIES WAS TAKEN IS ALSO GIVEN. THE NUMBER OF TRAPNIGHTS IS 4 TIMES THE NUMBER OF BURROWS TRAPPED IN EACH CASE SINCE 2 TRAPS WERE USED IN EACH BURROW FOR 2 NIGHTS

Dates and No. of Burrows Trapped		*Peromyscus leucopus*	*Peromyscus maniculatus*	*Mus musculus*	*Blarina brevicauda*	*Zapus hudsonius*	*Microtus pennsylvanicus*	*Sorex cinereus*	Totals
22–24 Nov	No. taken	47	1	17	2				67
1970	No./100 trapnights	15.1	0.3	5.4	0.6				21.5
(78)	No. burrows	32	1	8	2				40
	% of burrows	41.0	1.2	10.3	2.6				51.2
28–30 March	No. taken	1	4	3	1			2	11
1971	No./100 trapnights	0.3	1.3	1.0	0.3			0.7	3.6
(75)	No. burrows	1	3	3	1			2	8
	% of burrows	1.3	4.0	4.0	1.3			2.6	10.7
30 May–1 Jun	No. taken	1	17	3		2			23
1971	No./100 trapnights	0.3	4.5	0.8		0.5			6.1
(94)	No. burrows	1	16	3		2			20
	% of burrows	1.1	17.0	3.2		2.6			21.3
22–24 Nov	No. taken	46		8	7		1		62
1971	No./100 trapnights	15.3		2.7	2.3		0.3		20.7
(75)	No. burrows	34		6	7		1		44
	% of burrows	45.3		8.0	9.3		1.3		82.7
18–20 Apr	No. taken	9	7	1			1		18
1972	No./100 trapnights	4.7	3.6	0.5			0.5		9.4
(48)	No. burrows	9	6	1			1		15
	% of burrows	18.8	12.5	2.1			2.1		31.3
(370)	No. taken	104	29	32	10	2	2	2	181
	No./100 trapnights	7.0	2.0	2.2	0.7	0.1	0.1	0.1	12.2
	No. burrows	77	26	21	10	2	2	2	127
	% of burrows	20.8	7.0	5.6	2.7	0.5	0.5	0.5	34.3

taken in snap traps for a rate of 7.0 per 100 trapnights. *Peromyscus maniculatus* and *Mus musculus* used them less, probably because they were less closely associated with the burrows. *Peromyscus leucopus* lived in the brushy areas along the dike itself, while the other 2 species lived primarily in the cultivated fields a few feet further away.

Overall, 181 small mammals were taken in the burrows (12.2 per 100 trapnights). However, the greatest utilization was in the fall (Table 2). In November 1970, 21.5 per 100 trapnights were taken and in November 1971, 20.7 were taken. Respective values for March 1971 and April 1972 were 3.6 and 9.4.

It is clear from these data that several species of mammals other than woodchucks are opportunistic users of woodchuck burrows.

There would seem to be several uses that mammals, both large and small, might make of the burrows. First, some individuals may live there permanently or over extended periods. These would seem to include perhaps some rabbits and white-footed mice in addition to the woodchucks. Some mammals may use the burrows as

as temporary cover, including many of the larger and some of the smaller mammals taken. Some individuals, especially of the smaller species, may simply have been exploring the burrows. This would not seem likely in the case of most of the larger mammals, because the large traps were set during the day and in the burrows in such a way as to capture animals that were inside, and thus presumably had spent the night there.

Subsequent to this work a meadow jumping mouse was found in a hibernating nest in this same dike (Jones and Whitaker 1976).

LITERATURE CITED

GRIZZELL, R. A. 1955. Hibernating jumping mice in woodchuck dens. Amer. Midl. Nat. 53:257–293.

HAMILTON, W. J., JR. 1934. The life history of the rufescent woodchuck, *Marmota monax rufescens*. Ann. Carnegie Mus. 23:85–178.

JONES, G. S., AND J. O. WHITAKER, JR. 1976. The fauna of a hibernation nest of a meadow jumping mouse, *Zapus hudsonius*. Can. Field-Nat. 90:169–170.

Seasonal Abundance of Common Phytophagous and Predaceous Insects in Kentucky Soybeans[1]

H. G. Raney and K. V. Yeargan[2]
Department of Entomology, University of Kentucky, Lexington, Kentucky 40506

Abstract

A 4-year study (1972–1975) was conducted to determine seasonal abundance of common phytophagous insects in Kentucky soybean fields. Populations of predaceous insects were sampled at 3 locations in 1975. Time of, and density at, peak abundance are presented for the green cloverworm *Plathypena scabra*, the bean leaf beetle *Cerotoma trifurcata*, the grape colaspis *Colaspis brunnea*, and the green stink bug *Acrosternum hilare*. The green cloverworm was the dominant defoliating species, while seed pods were attacked most frequently by the green stink bug and the bean leaf beetle. Populations of 3 prevalent groups of predators, *Orius insidiosus*, *Nabis* spp., and *Geocoris* spp., peaked at different times during the summer, with *O. insidiosus* being first and *Geocoris* last.

Introduction

Due to recent increases in soybean production in Kentucky, insect problems of this crop are receiving ever greater attention. Before an effective insect pest management program can be developed, the seasonal population dynamics of potentially important pest and beneficial species must be determined. Faunistic surveys of soybean insects in several other states have been reported (Kretzschmar 1948, Blickenstaff and Huggans 1962, Tugwell et al. 1973). These reports presented extensive lists of species, including many uncommon, and possibly transient species. Carner et al. (1974) and Shepard et al. (1974), have reported on the seasonal abundance of common insect pests and arthropod predators, respectively, in South Carolina soybean fields. To date, there have been no published reports dealing specifically with the insects of Kentucky soybeans.

Materials and Methods

Insect samples were taken at approximately 2-week intervals in variety–trial plots planted by the Department of Agronomy, University of Kentucky, during 1972–1974 using a ground cloth and plant shake method similar to that of Boyer and Dumas (1963). Analysis of variance showed only negligible differences in insect abundance among the varieties, so results were pooled across varieties. The number of samples taken varied with location depending on the number of varieties present, but in all cases 30 or more sample units per location were taken on each sampling date. Each sample unit consisted of 3 linear feet (0.91 m) of row, with 1.5 feet (0.46 m) being taken from each of 2 adjacent rows.

During 1975, all samples were taken from fields of 'Williams' variety soybeans at approximately 7- to 10-day intervals. Nine contiguous plots, each 75 × 75 feet (22.85 × 22.85 m), were established in large fields. Three ground cloth samples as described above were taken randomly from each of the 9 plots. In addition, 2 sweep net samples were taken from each of the 9 plots to provide data on those insects, such as leafhoppers, which could not be adequately sampled by the ground cloth method. Each sweep net sample consisted of 20 sweeps across the row, using a 15-inch (0.38-m) diameter sweep net. Insects in the ground cloth samples were always counted in the field, while sweep net samples were taken to the laboratory for counting. A microscope was used for counting small insects, such as leafhoppers.

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[2] Associate Extension Professor and Assistant Professor, respectively.

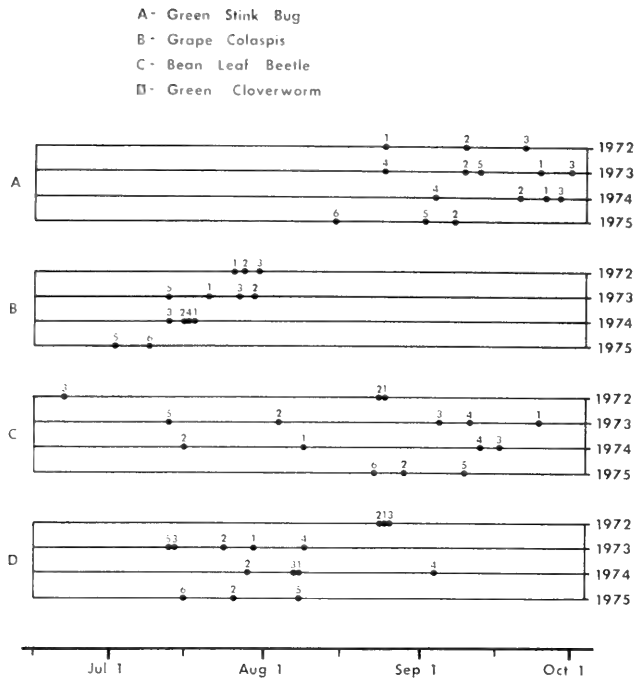


FIG. 1. Time of occurrence of peak population density of 4 species of phytophagous insects on soybeans in Kentucky. County locations are: 1, Fulton; 2, Caldwell; 3, Henderson; 4, Ohio; 5, Fayette; 6, Hardin.

Phytophagous species were counted during the entire study, but predaceous species were counted only during 1975. Sampling was begun when plants were in early bloom and continued until after pod maturity.

Soybean insects were sampled in the following counties during 1 or more years of this study: (1) Fulton, (2) Caldwell, (3) Henderson, (4) Ohio, (5) Fayette, (6) Hardin. The numerical designations given those counties is used consistently throughout this paper. The locations sampled each year were as follows: 1972, Locations 1, 2, 3; 1973, Locations 1, 2, 3, 4, 5; 1974, Locations 1, 2, 3, 4; and 1975, Locations 2, 5, 6.

Although quantitative data were collected on more than 20 species of insects during this study, we have chosen to present data on 4 phytophagous species and 3 predaceous genera. The phytophagous species discussed are the green cloverworm *Plathypena scabra*, the bean leaf beetle *Cerotoma trifurcata*, the grape colaspis *Colaspis brunnea*, and the green stink bug *Acrosternum hilare*. The predaceous groups discussed are damsel bugs *Nabis* spp., big-eyed bugs *Geocoris* spp. (primarily *G. puntipes*), and minute pirate bug *Orius insidiosus*. These taxa were chosen because of their consistent occurrence and relatively high numbers compared to the other taxa collected.

RESULTS AND DISCUSSION

Data collected at 3 to 5 locations each of the 4 years of this study provided 15 separate seasonal population trends for several phytophagous insect species. The time of peak abundance and mean density at peak abundance are given in Fig. 1 and Table 1, respectively, for green cloverworm, bean leaf beetle, grape colaspis, and green stink bug.

During 1973–1974, green cloverworm larval populations reached peak abundance between approximately mid-July and mid-August. The one aberrant location (#4) in 1974 may have been related to the late planting of soybeans. Population peaks of the green cloverworm in 1972 occurred several weeks later than the average for the other years. It is interesting to note that Carner et al. (1974) obtained very similar results in South Carolina. From sampling 3 locations there, they also found that green cloverworm populations peaked approximately 1 month later in 1972 than in 1973. This suggests that some geographically wide-range climatic factor may have influenced green cloverworm populations during those years.

There was considerable temporal variation in adult bean leaf beetle population peaks (Fig. 1). In the majority of cases, however, peaks occurred late in the season. Studies conducted in Illinois indicated that the bean leaf beetle, whose larvae feed on the roots of various legumes, has 2 generations per year (Kogan et al. 1974). They found that presumably overwintered adults were very scarce in soybeans after late June; first generation adults appeared in July and August while second generation adults emerged in September. If the life history of this species is similar in Kentucky, our data indicate that its peak abundance may occur either early (first generation) or late

TABLE 1.—MEAN DENSITIES PER 3-FOOT (0.91-M) OF ROW OF 4 PHYTOPHAGOUS INSECT SPECIES AT PEAK ABUNDANCE ON SOYBEANS IN KENTUCKY. MEAN VALUES ARE FOLLOWED BY ± STANDARD ERROR

		Year			
	Location[1]	1972	1973	1974	1975
Green Cloverworm (larvae)	1	12.4 ± 7.1	2.6 ± 0.3	13.9 ± 0.6	1.7 ± 0.4
	2	7.6 ± 0.1	8.5 ± 0.7	9.8 ± 0.9	1.7 ± 0.4
	3	3.4 ± 0.3	8.4 ± 0.5	10.8 ± 0.5	—
	4	—	11.5 ± 1.0	8.5 ± 0.6	—
	5	—	6.2 ± 0.5	—	7.3 ± 0.7
	6	—	—	—	6.8 ± 0.5
Bean Leaf Beetle (adults)	1	0.6 ± 0.2	1.2 ± 0.3	0.8 ± 0.2	—
	2	3.8 ± 2.3	3.2 ± 0.4	3.0 ± 0.6	1.2 ± 0.2
	3	1.5 ± 0.2	1.2 ± 0.2	0.5 ± 0.1	—
	4	—	1.6 ± 0.3	1.6 ± 0.3	—
	5	—	0.7 ± 0.2	—	0.8 ± 0.2
	6	—	—	—	2.4 ± 0.3
Grape Colaspis (adults)	1	2.4 ± 0.3	1.1 ± 0.2	1.6 ± 1.7	—
	2	0.9 ± 0.2	1.5 ± 0.2	0.5 ± 0.2	—
	3	1.4 ± 0.2	0.6 ± 0.2	1.4 ± 0.2	—
	4	—	—	0.1 ± 0.1	—
	5	—	0.9 ± 0.2	—	0.9 ± 0.2
	6	—	—	—	0.1 ± 0.1
Green Stink Bug (nymphs and adults)	1	1.2 ± 0.3	2.2 ± 0.3	1.3 ± 0.5	—
	2	0.2 ± 0.1	0.8 ± 0.2	1.2 ± 0.4	0.3 ± 0.1
	3	1.1 ± 0.3	0.5 ± 0.2	2.9 ± 0.5	—
	4	—	0.2 ± 0.1	0.1 ± 0.1	—
	5	—	1.0 ± 0.3	—	0.2 ± 0.1
	6	—	—	—	0.2 ± 0.2

[1] County locations are: 1, Fulton; 2, Caldwell; 3, Henderson; 4, Ohio; 5, Fayette; 6, Hardin.

(second generation), depending on location and year (Fig. 1). Soybean pods usually are at or near maturity by September in Kentucky, and these pods occasionally are damaged by adult bean leaf beetle feeding. If economic damage occurs from that species, it probably will result from feeding of colonizing adults on young seedlings or from unusually large populations of second generation adults feeding on soybean pods.

Populations of grape colaspis invariably peaked relatively early in the growing season at all of our sampling locations (Fig. 1). Data were not included from Location 4 in 1973 and Location 2 in 1975 because that species was virtually absent in those plantings. The biology and ecology of that beetle were studied in Arkansas, where it overwintered in the larval stage with adults emerging and ovipositing from June until mid-August (Rolston and Rouse 1965). Although they found that some second brood adults emerged in late summer and early fall, our data indicate that this does not occur in Kentucky soybeans. If such a second brood emerged, it occurred well after pod maturity and after our sampling was discontinued for the season. The relatively low adult densities of this species that we found on soybeans suggest that it poses little threat to this crop in Kentucky at the present time.

Because the green stink bug feeds on the soybean pods and developing seeds rather than foliage, it is not surprising that it is most abundant late in the season (Fig. 1). This insect feeds on other host plants earlier in the year, such as dogwood, blackberry, etc., and moves to soybeans when the pods begin to develop (Underhill 1934, Miner 1966). Due to its spotty distribution pattern and piercing–sucking type feeding damage, the insect and its feeding damage

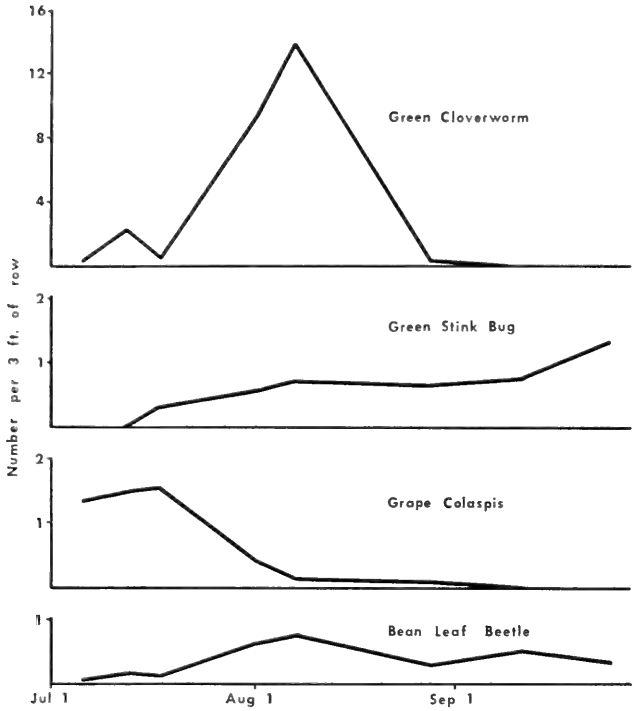


FIG. 2. Representative population trends of 4 species of phytophagous insects on soybeans in Kentucky; Fulton Co., 1974.

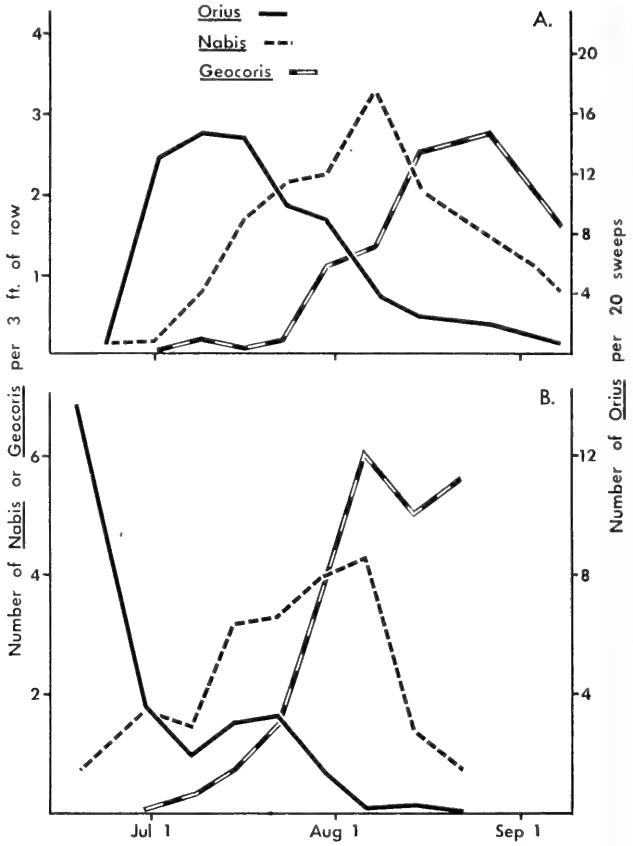


FIG. 3. Seasonal abundance of 3 species of predaceous insects on soybeans in Kentucky, 1975. A. Fayette Co. B. Hardin Co.

may go unnoticed during the growing season. Heavy stink bug feeding can, however, result in shriveled or otherwise deformed beans.

Representative seasonal population trends (Location 1, 1974) for green cloverworm, bean leaf beetle, grape colaspis, and green stink bug are given in Fig. 2. This illustrates the rates of population increase and decrease for these species.

In addition to the species discussed above, we collected population data on more than a dozen other phytophagous insect species, a few of which deserve mention. Based on our 1975 sweep net samples, the potato leafhopper *Empoasca fabae* was most abundant during the early part of the growing season. This was the most common leafhopper collected, reaching densities that gave mean estimates of more than 2 per sweep. In the same samples, all other leafhoppers combined did not exceed a mean of 1 per sweep. Very few aphids or spider mites were encountered.

Certain pests found in other parts of the country, such as the Mexican bean beetle *Epilachna varivestis*, were collected only in low numbers at our sampling locations. While other species of Lepidoptera were collected on soybeans, none were nearly as abundant nor as consistently present as the green cloverworm.

Among the beneficial insects collected, 3 groups of hemipteran predators were most prevalent. These were minute pirate bugs, damsel bugs, and big-eyed bugs, primarily *G. punctipes*. The population peaks of those 3 groups did not occur synchronously (Fig. 3). The earliest of the 3 was *O. insidiosus*, commonly found in association with large populations of thrips (*S. variabilis*) in 1975. Populations of *Nabis* spp. peaked near midseason at the time when green cloverworm populations usually were highest. Any predator–prey association between damsel bugs and green cloverworms remains to be shown, but their population synchrony invites further study. The last of these 3 predator groups to appear in

Kentucky soybeans were the big-eyed bugs. At the Fayette County location, *Geocoris* spp. populations peaked in late August and began to decline in early September (Fig. 3A). At the Hardin County location, however, their populations apparently were still increasing when the mature soybean plants lost their leaves in late August (Fig. 3B). Numbers of those predators collected at the Caldwell County location in 1975 were too low for analysis.

A comparison of our data with those published from other states, indicates that Kentucky soybean insect populations are more similar to those of the Midwest than to those of the Deep South. The bean leaf beetle, the potato leafhopper, and *S. variabilis* were the most abundant soybean insects reported from Arkansas, Minnesota, and Missouri, respectively (Blickenstaff and Huggans 1962, Kretzschmar 1948, Tugwell et al. 1973). In all those states, the green cloverworm was reported as the most abundant lepidopteran pest, as in the present study. In South Carolina, however, the green cloverworm was but one of several lepidopteran species that commonly attacked soybeans (Carner et al. 1974).

Of the pest species we collected, the green cloverworm appears to be the dominant soybean defoliator, while the seed pods are attacked by stink bugs and, occasionally, bean leaf beetles. It appears, therefore, that soybean insect pest management research in Kentucky should be directed primarily toward these species.

LITERATURE CITED

BLICKENSTAFF, C. C., AND J. L. HUGGANS. 1962. Soybean insects and related arthropods in Missouri. Mo. Agric. Exp. Sta. Res. Bull. 803. 51 pp.

BOYER, W. B., AND W. A. DUMAS. 1963. Soybean insect survey as used in Arkansas. Coop. Econ. Insect Rept. 13:91–92.

CARNER, G. E., M. SHEPARD, AND S. G. TURNIPSEED. 1974. Seasonal abundance of insect pests of soybeans. J. Econ. Entomol. 67:487–493.

KOGAN, M., W. G. RUESINK, AND K. MCDOWELL. 1974. Spatial and temporal distribution patterns of the bean leaf beetle, *Cerotoma trifurcata*, on soybeans in Illinois. Environ. Entomol. 3:607–617.

KRETZSCHMAR, G. P. 1948. Soybean insects in Minnesota with special references to sampling techniques. J. Econ. Entomol. 41:586–591.

MINER, F. D. 1966. Biology and control of stink bugs on soybeans. Arkansas Agric. Exp. Sta. Bull. 708. 40 pp.

ROLSTON, L. H., AND P. ROUSE. 1965. The biology and ecology of the grape colaspis, *Colaspis flavida*, in relation to rice production in the Arkansas Grand Prairie. Arkansas Agric. Exp. Sta. Bull. 694. 31 pp.

SHEPARD, M., G. R. CARNER, AND S. G. TURNIPSEED. 1974. Seasonal abundance of predaceous arthropods in soybeans. Environ. Entomol. 3:985–988.

TUGWELL, P., E. P. ROUSE, AND R. G. THOMPSON. 1973. Insects in soybeans and a weed host. Arkansas Agric. Exp. Sta. Rep. Serv. 214. 18 pp.

UNDERHILL, G. W. 1934. The green stink bug. Virginia Agric. Exp. Sta. Bull. 294. 26 pp.

Seasonal Molt in the White-footed Mouse *Peromyscus leucopus*[1]

Barbara A. Lensing
Department of Biology, University of Louisville, Louisville, Kentucky 40208

Abstract

White-footed mice were snaptrapped in and around Louisville, Kentucky, from July 1973 to July 1974 to study seasonal molt of wild adults. Previous investigators assumed that these mice molt seasonally, but it has been unknown whether or not 1 or more molts occurred each year or just how the molts coincided with the reproductive cycle.

The 94 adult specimens taken during the study indicate that there is, in fact, 1 seasonal molt each year and that it occurs in October, November, and December. Those months coincide approximately with the nonbreeding period and the short photoperiod. The actual pattern of new hair growth in adults resembles that of the juvenile molt.

Introduction

Mice of the genus *Peromyscus* have been some of the most extensively studied small mammals, and pelage and molting phenomena have been described in a number of species. Like many mammals, *Peromyscus* grows and molts 2 coats of hair before adulthood is reached. There is no standard nomenclature to describe such pelage changes as there is for the various avian plumages. In order of appearance after birth, the pelages and their subsequent molts will hereafter be termed (1) juvenile pelage (molt) and (2) subadult pelage (molt). They also are commonly referred to as maturational or developmental pelages (molts).

At maturity, the adult pelage must be shed periodically and be replaced if it is to continue to fulfill adequately its various functions. The adult pelages and molts have not been investigated as thoroughly in *Peromyscus* as have the developmental pelages. But it has been well shown that many other adult mammals exhibit seasonal moltings controlled by photoperiod through its effect on the pituitary (Ling 1970).

It is generally assumed that adult *Peromyscus* undergo seasonal pelage changes, but there have been few specific investigations of the subject. Since hair growth cycles seem to be established early in life and subsequent cycles may in fact repeat those early events, it is important to be familiar with the developmental molts. King (1968) presented a short comparative survey of the developmental molts for the genus, but gave no information for seasonal molts.

Gottschang (1956:517–519) gave a specific description of juvenile molt in *P. leucopus noveboracensis*. New rufous fur first begins to grow in a small patch or in a narrow line slightly dorsal and anterior to the hind leg. This narrow line of new hair growth moves forward, and about the time it reaches the front legs, a small patch of new hair appears on the shoulders. The shoulder patch and lateral stripe then enlarge until they meet, thus forming a continuous line along the side that separates the white ventral fur from the dark mouse gray of the rest of the back. The lateral rufous stripes continue to increase in width while a cinnamon rufous patch appears on each cheek just beneath the eye. The eye patch enlarges to replace all the gray on the sides of the face. By then, the lateral rufous stripe has extended from the hind leg back to the base of the tail. The juvenile gray fur down the center of the back is then replaced by rufous adult fur. The last juvenile fur to be replaced is either that at the very base of the tail or that across the top of the shoulders and between the ears. Males and females exhibit the same molting pattern (Fig. 1).

[1] Contribution No. 174 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

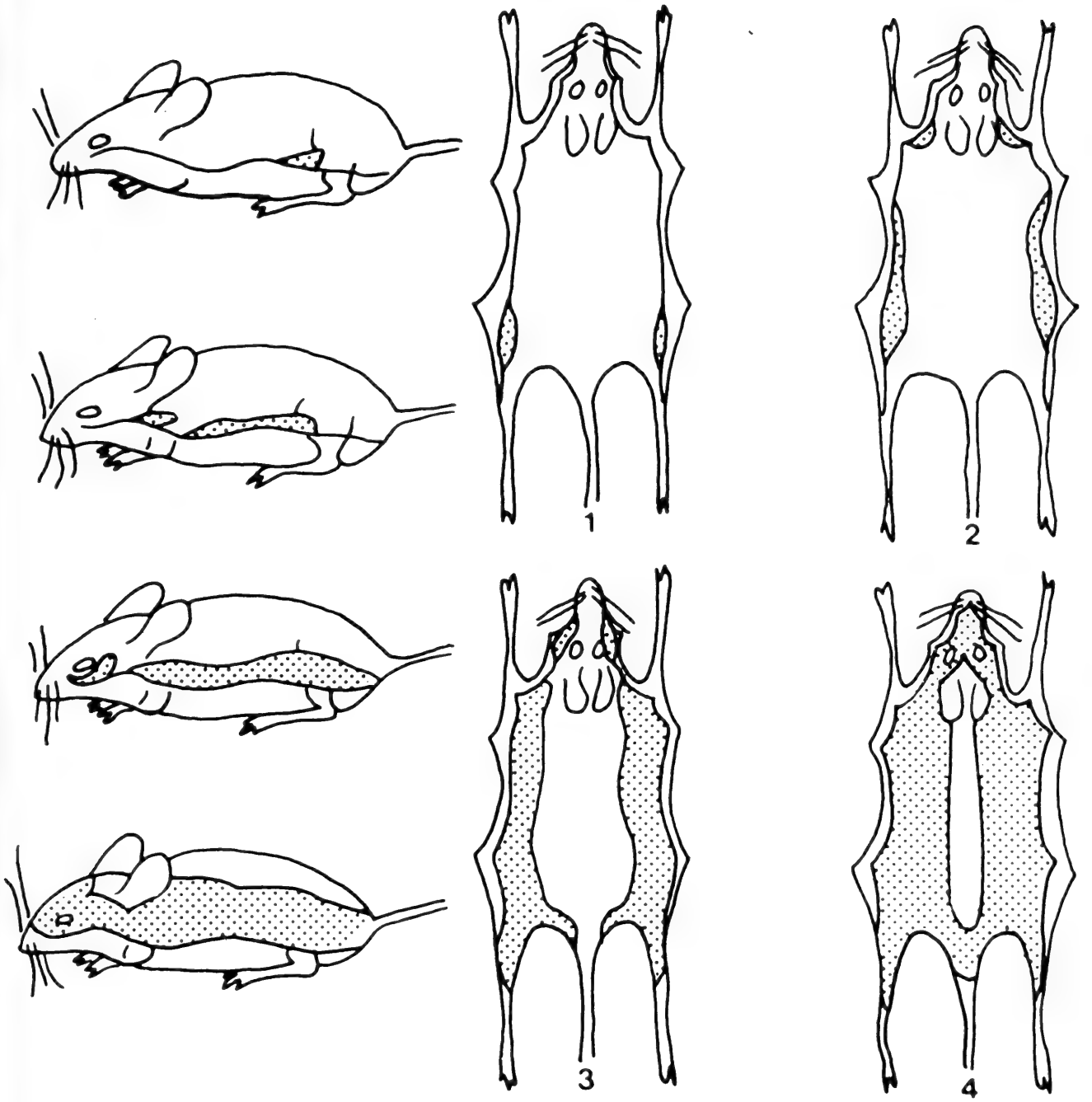


FIG. 1. Typical juvenile molt pattern for *Peromyscus leucopus noveboracensis* (after Gottschang 1956). Stippled areas represent new adult pelage.

Collins (1923) was the first to study adult molt in the genus. He did laboratory and field work on *P. maniculatus gambeli*, and concluded that the maximum amount of molting occurred in fall and early winter (September through December). "The most obvious characteristic of the seasonal molts is the absence of sharply defined molting periods. . . . Specimens may be found undergoing some change of pelage any month of the year." (Collins 1923:64, 66).

Brown (1963) found 2 seasonal pelages in adult *P. boylii* with most individuals exhibiting molt in spring (April–May) and fall (November–December). A spring and fall molt were also characteristic of *Ochrotomys nuttalli* (Linzey and Linzey 1967).

Lynch (1973) used adult *P. leucopus* in his laboratory study of the effects of changing photoperiod and temperature on the seasonal molts and reproductive system. He found that the seasonal molt and gonadal regression were exhibited only by mice

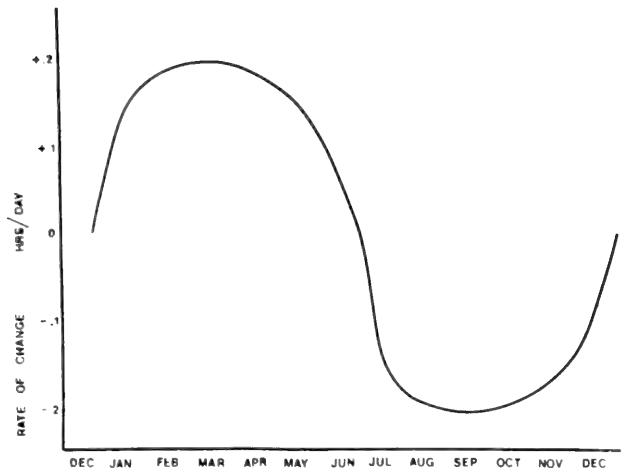


FIG. 2. Rate of change in photoperiod for Louisville, Kentucky (approximately 38°N latitude).

under a short-day photoperiod (9 hours light, 15 hours dark), and that short-day, cold-exposed (5 C) mice molted 2 weeks earlier than did warm (26 C) short-day mice. Short photoperiod had a more dramatic effect on the rate of seasonal molt than it did on the rate of regression of the reproductive system. Lynch assumed that the short-day seasonal molt was a fall molt.

Thus, it seems true of adult *Peromyscus*, as it seems for other wild adult mammals, that several environmental factors control seasonal molt, but photoperiod may be the major one. The reproductive cycle is also mainly under photoperiodic control, so one would expect that individual breeding condition, as well as ambient and microclimatic temperatures and behavioral adaptations would also have varying effects on seasonal molt.

METHODS AND MATERIALS

One hundred forty-eight mice for the study were snaptrapped in and around Jefferson County, Kentucky (approximately 38° N latitude), and were prepared as flat study skins. Standard measurements for each animal at the time of skinning included: lengths of tail, hind foot, and ear, and total length, total weight, size and position of testes, and notation of pregnancy or lactation. The adrenal glands were measured and preserved. Most specimens were collected between July 1973 and July 1974, although several skins were from the University of Louisville collection and date from 1964. All skins are on deposit at the University of Louisville. Each skin was categorized as juvenile, subadult, or adult on the bases of weight, breeding condition, and color of fur. Of the 148 mice, 94 were adult; only adults were used in assessing seasonal molt.

To determine the amount of seasonal molting, skins were placed in the following 4 groups based on the rate of change in photoperiod at 38° N latitude: summer (23 May–24 July), fall (24 July–23 November), winter (23 November–21 January), and spring (21 January–23 May). The rate of change in photoperiod for fall and spring was higher (between ±.15 and ±.20 hour per day) than the rate of change for summer and winter (between 0 and ±.15 hour per day) (Fig. 2).

Each skin was appraised for molt by inspecting the amount of pigment deposition in the skin itself. This is seen best on the underside of the skin. Seldom was a molt line visible in the fur, and, if so, only with respect to the developmental molts. The total area of each skin was determined by making tracings of the underside of the skin on clear plastic sheets of uniform thickness. The total area was then divided into molting and nonmolting areas on the basis of pigment deposition, and each area was cut out and weighed on a balance accurate to 1 mg. Weight was used to calculate the percentage of each skin in the process of molting, and from those weights, seasonal percentages were determined for each seasonal group.

The most characteristic patterns of new hair growth could also be seen by inspection of the underside of each skin, and those patterns were arbitrarily divided into 5 basic groups (Fig. 3). Each skin was categorized as Pattern I, II, III, IV, V, No Molt, or Diffuse Molt. The percentages of individuals in each category then could be calculated for summer, fall, winter, and spring.

Size of adrenal glands was recorded for 66 mice, and mean seasonal size was determined.

TABLE 1.—PERCENTAGES OF MALE, FEMALE, AND TOTAL *PEROMYSCUS LEUCOPUS* SHOWING MOLT AT DIFFERENT SEASONS, LOUISVILLE, KENTUCKY

	Summer	Fall	Winter	Spring
Males				
Number	6	22	12	10
Mean ± 2 SE	7.8 ± 7.3	28.1 ± 11.7	24.4 ± 10.3	0.6 ± 0.7
SD	8.9	25.2	17.9	1.1
Range	0–25.5	0–97.9	0–52.8	0–3.4
Females				
Number	0	19	13	12
Mean ± 2 SE	–	22.2 ± 12.4	19.0 ± 11.4	0.1 ± 0.1
SD	–	27.0	20.6	0.3
Range	–	0–85.6	0–68.7	0–0.9
Total				
Number	6	41	25	22
Mean ± 2 SE	7.8 ± 7.3	25.4 ± 8.1	21.6 ± 7.7	0.3 ± 0.3
SD	8.9	25.9	19.2	0.8
Range	0–25.5	0–97.9	0–68.7	0–3.4

RESULTS

Percentages of molt in progress in each of the 4 seasonal groups based on rate of change in photoperiod are shown in Table 1. The largest mean was always in fall, with the second largest mean in winter, and the smallest mean in spring. There was a significant difference between the amount of molting in fall and the amount in summer and spring. There also was a significant difference between the amount of molting in winter and spring. There was significantly more molting in progress in fall and winter males and females than in spring males and females. There also was significantly more molting in fall males than in summer males. No comparisons could be made for summer females since none was caught during the study.

The most common patterns of molt are shown in Fig. 3 and are arranged in sequence I–V to resemble Gottschang's (1956) drawings (Fig. 1) which show origin and direction of the juvenile molt. Fig. 3 is not a dynamic series even though it is probable that adult patterns of molt follow closely the juvenile pattern. Pattern I represents those skins that show pigment deposition in the axillae of the fore- and/or hindlimbs. Pattern II represents skins with pigment deposition and a narrow band along the lateral lines from the axillae of the forelimbs to those of the hindlimbs. The

TABLE 2.—PERCENTAGES OF INDIVIDUAL *PEROMYSCUS LEUCOPUS* SHOWING DIFFERENT PATTERNS OF MOLT, LOUISVILLE, KENTUCKY. (SEE TEXT FOR DESCRIPTION OF PATTERNS)

	Pattern						
	I	II	III	IV	V	Diffuse	Total
Summer	16.6	–	–	–	–	33.3	49.9
Fall	9.7	9.7	19.5	19.5	17.1	–	75.6
Jul–Aug	9.1	9.1	–	9.1	9.1	–	36.6
Oct	–	–	30.0	40.0	20.0	–	90.0
Nov	15.0	15.0	25.0	15.0	20.0	–	90.0
Winter	8.0	16.0	24.0	16.0	8.0	–	72.0
Spring	13.6	–	–	–	4.5	–	18.2

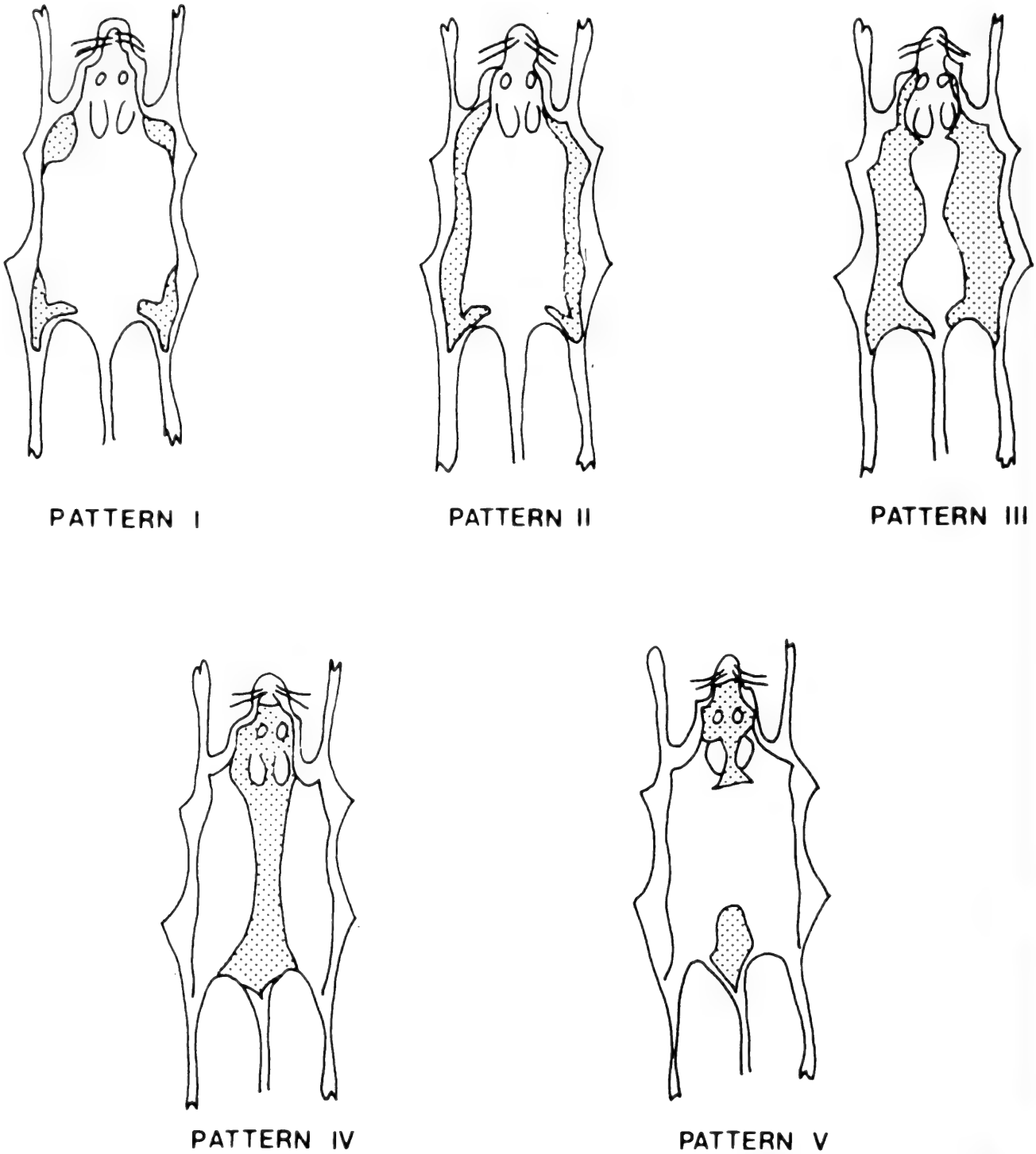


FIG. 3. Categories of patterns of molt in adult *Peromyscus leucopus*. Stippled areas represent regions of new hair growth. See text for explanation of patterns.

third pattern is the most variable in the sequence and symbolizes skins with pigment lines midway up the sides parallel to the lateral lines. Those 2 pigment lines may or may not be connected by pigment deposited across the dorsum. The lines vary greatly in width, and may extend from the lateral line almost to the mdidle of the back. Pattern IV depicts skins with pigment laid down in a single middorsal line from between the eyes to the base of the tail. Pattern V represents skins with pigment on the head (around and between the eyes and ears) and/or at the base of the tail. The pigment deposition represented by each of the 5 patterns is almost always bilaterally symmetrical.

The highest percentage of individuals

TABLE 3.—SIZE (GREATEST LENGTH, MM) OF ADRENAL GLANDS OF ADULT MALE AND FEMALE AND ALL *PEROMYSCUS LEUCOPUS* EACH SEASON, LOUISVILLE, KENTUCKY

	Summer	Fall	Winter	Spring
Males				
Number	4	15	5	9
Mean ± 2 SE	3.5 ± 0.3	2.5 ± 0.3	2.7 ± 0.2	2.7 ± 0.3
SD	0.4	0.7	0.3	0.4
Range	3.2–3.8	1.5–3.8	2.4–3.0	2.2–3.5
Females				
Number	0	15	6	12
Mean ± 2 SE	–	2.9 ± 0.3	2.3 ± 22.0	2.3 ± 18.0
SD	–	0.6	0.3	0.3
Range	–	2.4–4.0	2.0–2.7	2.0–2.9
Total				
Number	4	30	11	21
Mean ± 2 SE	3.5 ± 0.3	2.7 ± 0.4	2.5 ± 0.9	2.5 ± 0.2
SD	0.4	0.7	0.3	0.4
Range	3.2–3.8	1.5–4.0	2.0–3.0	2.0–3.5

showed molt in fall (75.6%) and winter (72%), while the lowest percentage was in spring (18.2%) (Table 2). When the fall group was broken down into 3 subgroups, the percentages were highest in October and November (both 90%). Winter was represented by mice caught only in December. So, October, November, and December were the months with the highest percentages of individuals showing molt.

Sizes of adrenal glands for the 4 seasons are shown in Table 3. Adrenal glands in summer are significantly larger than at any other time of year, and the male adrenal gland is significantly larger in summer than in fall, winter, or spring. No females were collected in summer during the study, but the females did have significantly larger adrenal glands in fall than in winter or spring.

DISCUSSION

Although some adult *P. leucopus* can be found in the process of molting at any time of year, there is but 1 annual molt. It occurs in fall and winter (specifically October, November, and December) when the rate of decrease in photoperiod is greatest. But those months do not coincide exactly with the greatest rate of change in the fall photoperiod between 24 July and 23 November. That time lag fits in with the general nature of hormonal control; hormone levels build up slowly in the bloodstream and must reach a certain critical level before stimulating any physiological changes.

It is also known that *P. leucopus*, from approximately the same locality as the present study group, are in breeding condition all months except November, December, and January (Thane Robinson pers. comm.). This is essentially in agreement with the findings of Burt (1940) and Whitaker (1940) at Ann Arbor, Michigan, who reported that few young were produced in November and none in December, January, or February. Most litters were produced in April, May, and June. A slump occurred in July, but production was up again in August, September, and October.

Since Hayward (1965) has shown that *P. maniculatus* does not need to grow a warm winter coat, the fact that the nonbreeding months overlap the months of the annual molt probably is no coincidence. October, November, and December must represent the most energetically feasible time of the year to molt with respect to the reproductive cycle.

These findings agree with Osgood's

(1909) belief that *Peromyscus* undergoes only 1 seasonal molt in the fall and with Collins's (1923) field study which showed a fall molt (October and November) in *P. maniculatus*. Brown (1963) and Lynch (1973) are the only investigators who attempted to relate adult molting to photoperiod and the reproductive cycle. *P. boylii* apparently has 2 seasonal molts (fall and spring) that coincide with the ends of breeding periods. Laboratory reared *P. leucopus* come out of breeding condition and exhibit molting when exposed to short photoperiod, but the seasonal timing of the molt in wild white-footed mice has not been determined previously.

Adult *P. leucopus* do adhere to definite patterns of new hair growth and those patterns resemble those of the juvenile molt (Table 2). Only in the summer group did any individuals exhibit molt with a diffuse pattern.

Just how size of adrenal glands relates to seasonal molting is not known. But adrenal gland size is a known indicator of the amount of environmental stress in small mammals, and stress probably can modify the effects of a major environmental cue like photoperiod.

The present study helps confirm the belief that photoperiod is the major environmental cue to trigger seasonal molt in wild adult *P. leucopus*, as it is in many other wild animals. Also, it shows how tightly linked are the 2 energy costly events of reproduction and new hair growth. Other less important factors probably modify the main environmental cue so that some individuals may be found molting at any time of year. Only 1 seasonal molt was typical of *P. leucopus* at 38° N latitude, but depending on the latitude and the breeding cycle, there may be 2 seasonal molts per year, as there are in *P. boylii* and *Ochrotomys nuttalli*.

Literature Cited

Brown, L. N. 1963. Maturational and seasonal molts in *Peromyscus boylii*. Amer. Midl. Nat. 70:466–469.

Burt, W. H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Misc. Publ. Mus. Zool. Univ. Mich. 45:1–58.

Collins, H. H. 1923. Studies of the pelage phases and of the nature of color variation in mice of the genus *Peromyscus*. J. Exp. Zool. 38:45–107.

Gottschang, J. L. 1956. Juvenile molt in *Peromyscus leucopus noveboracensis*. J. Mammal. 37:516–520.

Hayward, J. S. 1956. Microclimate temperature and its adaptive significance in six geographical races of *Peromyscus maniculatus*. Can. J. Zool. 43:341–350.

King, J. A., Ed. 1968. Biology of *Peromyscus*. Spec. Publ. No. 2, Amer. Soc. Mammal. 593 pp.

Ling, J. K. 1970. Pelage and molting in wild animals with special reference to aquatic forms. Quart. Rev. Biol. 45:16–54.

Linzey, D. W., and A. V. Linzey. 1967. Maturational and seasonal molts in the golden mouse, *Ochrotomys nuttalli*. J. Mammal. 48: 236–241.

Lynch, G. R. 1973. Effect of simultaneous exposure to difference in photoperiod and temperature on the seasonal molt and reproductive system of the white-footed mouse, *Peromyscus leucopus*. Comp. Biochem. Physiol. 44A:1373–1376.

Osgood, W. H. 1909. Revision of the mice of the American genus *Peromyscus*. N. Amer. Fauna 28:1–285.

Whitaker, W. L. 1940. Some effects of artificial illumination on reproduction in the white-footed mouse, *Peromyscus leucopus*. J. Exp. Zool. 83:33–60.

The "Lost" Liliaceae of Kentucky: A Reevaluation[1]

EDWARD T. BROWNE, JR.
Department of Biology, Memphis State University, Memphis, Tennessee 38152

AND

RAYMOND ATHEY
701 Woodland Avenue, Paducah, Kentucky 42001

ABSTRACT

Melanthium virginicum L. is reported for Kentucky the first time in more than 130 years. Evidence of the occurrence of *Maianthemum canadense* Desf. in Kentucky is given, and *Lilium philippinense* Baker is reported for the first time as a naturalized escape.

In an earlier article (Browne 1962), species of Liliaceae were discussed which had last been collected in Kentucky 100 years or more ago or had never been collected in the state although their distribution in adjacent states indicated a likelihood of their occurrence in Kentucky. Two species have now been collected, and a third species, not expected in Kentucky, has been discovered.

The acronyms F, GH, MO, NCU, NY, PH, and US that designate the herbaria referred to in this paper follow the usage of Lanjouw and Stafleu (1964) which is now almost universally adopted in reference to herbaria.

It has been largely through the efforts of the second author that these records have been established. All collections are represented by specimens in the Herbarium, Memphis State University. Extra collections have been distributed to NCU and other herbaria as permitted by the availability of material. For the sake of brevity, the names of the collectors are abbreviated RA and ETB followed by their collection number.

Melanthium virginicum.—As reported earlier, the only known records of this species in Kentucky are 2 sheets in NY collected by Dr. C. W. Short in 1842. No other data are known for those collections since the information furnished by Short is minimal. Specimens cited: Calloway County, RA, 2398.

Maianthemum canadense.—Wharton and Barbour (1971) illustrated this species, but gave no distributional data, in the absence of which and without voucher specimens, their illustration cannot be considered adequate to establish a state record. Dr. Barbour (pers. comm.) told both of us on separate occasions where the species was photographed. On the basis of that information, the second author made voucher collections. It is our understanding that *M. canadense* also occurs in an adjacent county, but we have no specimens to support that contention. Specimens cited: Menifee County, RA, 2378.

**Lilium philippinense*.—This species was collected by the first author while on a field trip in eastern Kentucky in 1972. It is thoroughly established in a large field and along roadsides in that locality. From that author's experience with this species in Georgia, it is clear that it must have escaped from some flower garden in the vicinity. It is somewhat surprising that a report of its occurrence in the state has not been made previously, so great is the reproductive potential and widespread its distribution at that locality. Specimens cited: McCreary County, ETB 72H14.1.

This species differs from *L. formosanum* Wallace (*L. philippinense* Baker var. *formosanum* [Wallace] Wilson apud Grove in Wilson 1925) in the shorter pedicels, nonstoloniferous bulbs (Wilson was not sure of this), glabrous stems, shorter ovulary, nonangular fruit, pointed (rather than de-

[1] Contribution No. 7, Kentucky Flora Project, Memphis State University.

pressed) fruit summit, and the stamens slightly exceeding the perianth. The perianth at the base is about the diameter of an ordinary wooden pencil in living material, a character used by the late Dr. Samuel L. Emsweller, USDA (pers. comm.), as a separating characteristic. This is considerably greater in *L. formosanum*. The leaves of our specimens are wider (6–10 mm) than reported by Wilson (2–4 mm), but that might vary depending upon environmental conditions. It seems apparent from this study that *L. philippinense* and *L. formosanum* probably are not distinct species, but the answer to that problem is beyond the scope of this paper. *L. philippinense* is here recognized as an introduced, naturalized taxon by the asterisk preceding the generic name.

Appreciation is expressed to the curators and staffs of the following herbaria whose kindness and help to a great extent made possible this publication: F, GH, MO, NY, PH, and US.

LITERATURE CITED

BROWNE, E. T., JR. 1962. "Lost" species of Kentucky Liliaceae. Trans. Ky. Acad. Sci. 23 (3–4):51–57.

LANJOUW, J., AND F. A. STAFLEU. 1964. Index Herbariorum. Ed. 5. Int. Bur. Pl. Taxon. Nomen., A. I. P. T., Utrecht, Netherlands.

WHARTON, M. E., AND R. W. BARBOUR. 1971. The wildflowers and ferns of Kentucky. Univ. Press Ky., Lexington, Ky. 344 pp.

WILSON, E. H. 1925. The lilies of eastern Asia. Dulau, London, Eng.

A Note on the Distribution of *Chrosomus erythrogaster* (Cyprinidae) in Kentucky

THOMAS M. FREEZE AND KATHY J. RAYBURN
Department of Biology, Murray State University, Murray, Kentucky 42071

ABSTRACT

The distribution of the southern redbelly dace *Chrosomus erythrogaster* in western Kentucky includes the Gulf Coastal Plain, based on collections from the Tennessee River drainage in Calloway County.

Clay (1975) reported that the distribution of the southern redbelly dace *Chrosomus erythrogaster* is statewide in Kentucky with the probable exception of the Gulf Coastal Plain. The collections reported by Woolman (1892), Sisk (1969), Smith and Sisk (1969), Resh et al. (1973), Jones (1974 unpublished master's thesis, Murray State University, Murray, Kentucky), and Webb and Sisk (1975) in or bordering the Coastal Plain area of Kentucky did not contain any specimens of *C. erythrogaster.*

Distributional records within the Coastal Plain area of other states include an isolated population in the Yazoo River drainage near Vicksburg, Mississippi, documented by Hemphill (1957), and a record from the Obion River system of western Tennessee that presumably is valid (Sliger pers. comm.). *C. erythrogaster* is distributed widely in the eastern drainage of the Tennessee River in Tennessee (Sliger pers. comm.). Buchanan (1973) reported *Phoxinus (= Chrosomus) erythrogaster* from the St. Francis River drainage within the Mississippi Alluvial Plain in Arkansas, but Pflieger (1975) did not record it from the "Lowlands" of southeastern Missouri within the same drainage.

On 24 June 1976, 2 specimens of southern redbelly dace (MSUMZ 744) were collected in east-central Calloway County, Kentucky, within the reaches of the Gulf Coastal Plain. One was collected from Little Sugar Creek at the Highway 732 bridge about 8 km east of Highway 94 and 13 km due south of Kentucky Lake State Park. The second specimen was collected from the nearby boil of Russells Chapel Spring that empties into Little Sugar Creek. Little Sugar Creek empties into the Blood River Embayment on the western side of Kentucky Lake (Tennessee River).

These collections apparently represent the first records of *C. erythrogaster* from the Tennessee River drainage within the Coastal Plain of western Kentucky. It is believed that the specimens are indicative of an established population, since both were exhibiting breeding coloration.

We express appreciation to Dr. Andrew Sliger and his ichthyology class for their assistance in securing the above specimens.

LITERATURE CITED

BUCHANAN, T. M. 1973. Key to the fishes of Arkansas. Ark. Game Fish Comm., Little Rock, Ark. 170 pp.

CLAY, W. M. 1975. The fishes of Kentucky. Ky. Dept. Fish Wildl. Res., Frankfort, Ky. 416 pp.

HEMPHILL, A. F. 1957. The southern redbelly dace, *Chrosomus erythrogaster erythrogaster*, from the lower Mississippi River drainage. Copeia 1957(1):53.

PFLIEGER, W. L. 1975. The fishes of Missouri. Mo. Dept. Cons., Jefferson City, Mo. 343 pp.

RESH, V. H., C. R. BAKER, AND W. M. CLAY. 1973. A preliminary list of fishes of the Land Between the Lakes, Cumberland and Tennessee river drainages. Trans. Ky. Acad. Sci. 33(3–4):73–80.

SISK, M. E. 1969. The fishes of west Kentucky. I. Fishes of the Clark's River. Trans. Ky. Acad. Sci. 30(3–4):54–59.

SMITH, P. L., AND M. E. SISK. 1969. The fishes of west Kentucky. II. The fishes of Obion Creek. Trans. Ky. Acad. Sci. 30(3–4):60–68.

WEBB, D. H., AND M. E. SISK. 1975. The fishes of west Kentucky. III. The fishes of Bayou de Chien. Trans. Ky. Acad. Sci. 36(3–4):63–70.

WOOLMAN, A. J. 1892. Report of an examination of the rivers of Kentucky with lists of the fishes obtained. Bull. U.S. Fish Comm. 1890: 249–289.

A White-flowered Form of *Iris cristata* from Carter County, Kentucky[1]

ARLAND HOTCHKISS
Department of Biology, University of Louisville, Louisville, Kentucky 40208

AND

KENNETH RAY WILSON
Box 507, R. R. #5, Olive Hill, Kentucky 41164

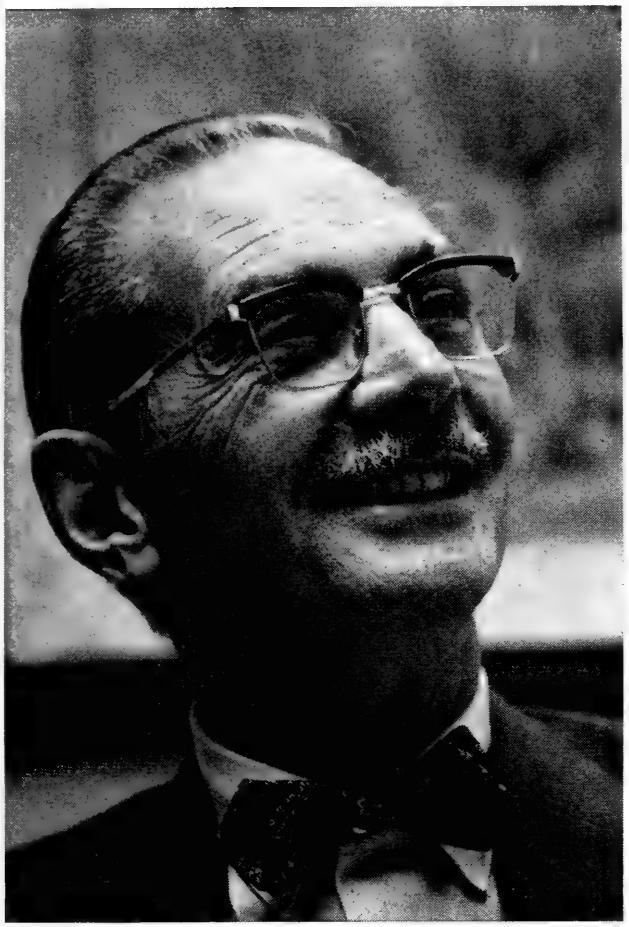
A white-flowered form of the dwarf, crested iris, *Iris cristata* Ait. was found among hundreds of typical blooming plants which here segregate into light blue and dark blue forms. It is completely white except for the yellow crest.

A white-flowered form known as var. *albá* Dykes is known in the horticultural treatises on *Iris* but apparently is rare in the field.

It was found on a steep, southwest facing, yellow clay bank of a small woodland stream near U.S. Highway 60 on the farm of Glendal Plummer at Gregoryville, Kentucky, in May 1972. It is presently known from this single collection and is maintained in cultivation by the junior author.

[1] Contribution No. 185 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

DISTINGUISHED SCIENTIST AWARD



Dr. Louis A. Krumholz

On behalf of the Academy's Board of Directors, I am pleased to have the privilege of making known to you the name of the Academy's 1976 Distinguished Scientist. The idea for such an award was spawned during a board meeting sometime in the past two years. This year's Board approved the award and also secured the approval and financial backing of the Executive Committee. Both groups are pleased that the award is now finally being instituted. Hopefully, the recipient of the award will be honored to be selected and I know that the Academy will be honored for being associated with the recipient.

The person who we honor this evening was born in the Pacific Northwest in the State of Washington, but unlike others who heeded the classic admonition to go west, decided to head back east for his fame and glory. He completed a baccalaureate degree at the College of St. Thomas in St. Paul, Minnesota, with a major in General Science, and a master of science degree at the University of Illinois with a major in Zoology.

Prior to enrolling at the University of Michigan to pursue a doctorate, he was employed for a while with the Illinois Natural History Survey. Apparently the type of research he undertook with the Survey, not only helped him to produce a doctoral dissertation in 1945 for the University of Michigan, but has been the basis of much of his subsequent research activities in Michigan, Indiana, Tennessee, Kentucky, and in the Bahamas.

Upon completion of his doctorate, he was hired by Indiana University as an instructor in zoology and also as a research associate with the Indiana Lake and Stream Survey. That employment lasted 5 years, after which he was employed for 4 years by TVA to be in charge of an ecological study of White Oak Creek, a creek that received a wide variety of effluents from the Oak Ridge National Laboratory.

Subsequently, he took an exotic position as Resident Biologist in charge of upkeep and all facilities and research at the Lerner Marine Laboratory at Bimini in the Bahamas.

Settling back to earth, he came to the University of Louisville in 1957. He was hired as an assistant professor, and by 1963 was promoted to full professorship; in 1966–1967 he served as Chairman of the Division of Natural Sciences. He was Director of the Water Resources Laboratory at the University of Louisville, a position to which he was appointed in 1967.

During his busy career he has found time to:

1. Direct, or at least be involved in, the research efforts of 70 master's and doctoral candidates, mostly at the University of Louisville but some at Indiana University.

2. Consult, in some way or another, for over 14 organizations, including the Oak Ridge Institute of Nuclear Studies, the National Academy of Sciences, the World

Health Organization, the President's Scientific Advisory Committee, U.S. Atomic Energy Commission, and the U.S. Army Corps of Engineers.

3. Present more than 20 scholarly papers at meetings, conferences, and symposia of national and international professional organizations.

4. Publish more than 90 research articles, mostly in research publications of national and international scope.

His teaching has apparently been reinforced by his research because he was named the 1976 Distinguished Faculty Lecturer at the University of Louisville.

He has served the Kentucky Academy of Science exceedingly well as its President and now, as the Editor of the Academy's official publication, the TRANSACTIONS.

The Academy's 1976 Distinguished Scientist is Dr. Louis A. Krumholz.

John C. Philley (Chmn)
Board of Directors

Response by Dr. Krumholz

Thank you very much Dr. Philley. I am most gratified and highly honored to have been selected for this award. It is beautiful, and certainly is a high spot in my career. At the same time, I am completely taken aback by such an honor since there are so many distinguished scientists in our Academy. I will do my best to live up to your confidence. Thank you, again.

ACADEMY AFFAIRS

PROGRAM

Friday, 19 November 1976

1300–1700 EST REGISTRATION, Room 137, Chemistry–Physics Building

1300–1800 SCIENTIFIC EXHIBITS, Room 137, Chemistry–Physics Building

1300–1530 SECTIONAL MEETINGS (see following pages)

1530–1730 PLENARY SESSION, Room 139, Chemistry–Physics Building (see below)

1700–1900 RECEPTION HOUR, Alumni House, Rose and Euclid Streets

1900– KAS ANNUAL BANQUET, Student Center Ballroom (NOTE: pick up tickets at registration desk)

Saturday, 20 November 1976

0700–1900 EST BREAKFAST SERVICE, Student Center Grill and elsewhere in vicinity

0800–1000 REGISTRATION, Room 137, Chemistry–Physics Building

0800–0930 ANNUAL BUSINESS MEETING, Room 139, Chemistry–Physics Building

0930– SECTIONAL MEETINGS (see following pages)

0930– PANEL DISCUSSION ON LIBRARIES (see below)

1100–1400 CAFETERIA SERVICE, Student Center and elsewhere

Special Programs

Friday, 19 November 1976, Room 139, Chemistry–Physics Building

Plenary Session

"Preservation and Protection of Natural Areas in Kentucky"
William H. Martin, Moderator

1530–1600 Preserving natural diversity. William H. Martin, Associate Professor of Biological Science, Eastern Kentucky University.

1600–1630 The 1976 Kentucky Nature Preserves Act. Jon E. Rickert, Attorney-at-law, Elizabethtown, Kentucky.

1630–1700 Scenic easements: protection by private ownership. Hon. Joseph C. Graves, State Senator, Lexington, Kentucky.

1700–1730 Community action: protection through land trust. Robert A. Kuehne, Associate Professor of Biology, University of Kentucky.

Saturday, 20 November 1976, Room 139, Chemistry–Physics Building

"The Library—Your Best Research Ally"

Marth Rush, President, Special Libraries Association, Kentucky Chapter, University of Louisville Law Library, Moderator
Panel Members

0920–1130 Trudi Belardo, Computer Based Literature Search, King Library, University of Kentucky.
Ellen Baxter, Department of Chemistry Librarian, University of Kentucky.
Mary Evelyn Minter, Medical Center Library, University of Kentucky.
Virginia Neal, Science Librarian, Western Kentucky University.

Botany and Microbiology

Room 108–109,
T. H. Morgan Biological Science Building
Harold E. Eversmeyer, Chairman, Presiding
Joe E. Winstead, Secretary

Friday, 19 November

1315 Bacterial cell separation in the absence of growth. A. D. Hitchins, John W. O'Donnell II, and Charles Gilvarg. T. H. Morgan School of Biological Sciences, University of Kentucky, and Department of Biochemical Sciences, Princeton University.

1330 Baseline data on the microbiota of air in an urban area. K. E. Bewley, W. R. Ranney, L. P. Elliott, and L. B. Lockwood. Department of Biology, Western Kentucky University.

1345 Anticandida and anticancer therapy in *Candida* infected AKR mice. Stephen E. Woock and David N. Mardon. Department of Biological Sciences, Eastern Kentucky University (Sponsored by Raymond B. Otero).

1400 Mouse marrow–thymus lymphocyte antigen: a new differentiation heteroantigen in rodents. Fernando Morgado. Department of Biology, Western Kentucky University.

1415 Phytoplankton dynamics in the Bayou du Chien, a stream of western Kentucky. Edward L. Johnson and Robert G. Johnson. Department of Biology, Murray State University.

1430 Gel electrophoresis in the genus *Tsuga*. Ronald R. Van Stockum, Jr. Department of Biology, University of Louisville.

Saturday, 20 November

0945 The Big Clifty Prairie, a remnant outlier of the Prairie Peninsula, Grayson County, Kentucky. William S. Bryant. Department of Biology, Thomas More College.

1000 Some effects of ground fire on the herbaceous and shrub strata in the knobs region of Marion County, Kentucky. Les McClain. Department of Science, Saint Catherine College.

1015 Rapid response to stimuli in plants. Anne Hotchkiss, Louisville Biology Section Winner of the Kentucky Junior Academy of Science.

1030 Information storage and retrieval system designed for the herbarium for Murray State University. Marian J. Fuller. Department of Biology, Murray State University.

1045 Bryophytes of the Red River Gorge. S. M. Moyle, G. M. Cheschier, and K. Wilhelmi. Department of Biology, Centre College of Kentucky.

1100 Bryophytes of Backusburg Hill, Calloway County, Kentucky. James Perry. Department of Biology, Murray State University (sponsored by M. J. Fuller).

1115 Interesting fern records from the Red River catchment area in Kentucky. Ray Cranfill. T. H. Morgan School of Biological Sciences, University of Kentucky (sponsored by W. J. Meijer).

1130 Vascular flora of the Sandy Branch drainage in Carlisle County, Kentucky. Larry Wilson. Department of Biology, Murray State University (sponsored by M. J. Fuller).

1145 Vascular flora of loess ravines in Carlisle, Hickman, and Fulton counties of Kentucky. Charlotte Bryan. Department of Biology, Murray State University.

1200 Election of officers for 1976–1977.

CHEMISTRY

Room 220, Chemistry–Physics Building
William R. Oliver, Chairman, Presiding
Ilyas Ahmad, Secretary

Friday, 19 November

1300 Sectional business meeting.

1315 Electrochemical carbon–halogen bond fission: 1e vs. 2e mechanisms. James E. O'Reilly. University of Kentucky.

1330 Proton excited x-ray fluorescence analysis of solid coal. S. Crouch Laumer and H. W. Laumer. Department of Chemistry and Department of Physics, University of Kentucky.

1345 Application of instrumental neutron activation techniques to coal analysis. G-H. Sun, W. D. Ehmann, and L. L. Chyi. Department of Chemistry and Institute of Mining and Minerals Research, University of Kentucky.

1400 Chemical studies of impact glasses and lunar agglutinates. W. B. Stroube, Jr. and W. D. Ehmann. Department of Chemistry, University of Kentucky.

1415 Chemical characterization of Apollo 16 lunar core samples by INAA. T. I. M. Hossain, M. Z. Ali, and W. D. Ehmann. Department of Chemistry, University of Kentucky.

1430 Photolysis of some substituted pyrroles. D. M. Bruser and J. M. Patterson. Department of Chemistry, University of Kentucky.

1445 The reaction between diphenyldiazo methane and methyl phenylpropriolate. Chester L. Leach and Joseph Wilson. Department of Chemistry, University of Kentucky.

1500 Some observations on the reaction of hydrazine with 3-benzylidene-phthalide. Victor I. Bendall and Beveraly Ann Phelps. Department of Chemistry, Eastern Kentucky University.

Saturday, 20 November

0930 Crystal structure of 4,4′-dichlorobiphenyl. Meii-Shiow Kuo and Carolyn P. Brock. Department of Chemistry, University of Kentucky.

0945 Thermal behavior of ethylenetetracarboxylic acid. Nabeel F. Haidar, Loren Braun, J. M. Patterson, and Walter T. Smith, Jr. Department of Chemistry, University of Kentucky.

1000 Effect of varying dosage of vitamin E on the body chemistry. Ilyas Ahmad and Charlotte Dingels. Department of Chemistry, Kentucky State University.

1015 The adsorbed phase of CS_2+acetone on a heterogeneous carbon surface. Marcellus T. Coltharp. Department of Chemistry, Kentucky State University.

1030 Break.

1045 Synthesis of maleic anhydride from aspartic acid. Loren Braun, Walter T. Smith, Jr., and J. M. Patterson. Department of Chemistry, University of Kentucky.

1100 Morphology of lead crystals grown in gels. Ms. Jo Reed, Kentucky Junior Academy of Science.

1115 The Skraup reaction with meta-substituted anilines. Ellis Brown. Department of Chemistry, University of Kentucky.

1130 A new criteria for the enhancement of incompletely resolved mass spectra and reconstructed gas chromatograms. Howard Erisman and Marshall Gordon. Department of Chemistry, Murray State University.

1145 Disproportionation equilibria for monosubstituted pentakis (aromatic isocyanide) cobalt (I) in solution. C. A. L. Becker. Department of Chemistry, Kentucky State University.

1200 Lunch.

1315 Investigation of mixed indicator effect in complexometric titration of cobalt (II). Dar-

nell Salyer and John Thomas Newton. Department of Chemistry, Eastern Kentucky University.

1330 Effect of heated and nonheated oils with varying degrees of unsaturation on the body chemistry and their relationship to vitamin E hypervitaminosis. Ilyas Ahmad and David S. Cornelius. Department of Chemistry, Kentucky State University.

1345 Computer simulation of the interaction of hydrogen with aluminum metal surfaces. Audrey L. Companion. Department of Chemistry, University of Kentucky.

1400 Base induced claisen rearrangement of bispopargyl ethers. B. Venugopalan. Department of Chemistry, University of Louisville.

GEOGRAPHY

Room 367, Chemistry–Physics Building
Phillip Phillips, Chairman, Presiding
W. A. Franklin, Secretary

Friday, 19 November

1300 The evolving Bluegrass Region of Kentucky: a half century of change, 1920–1970. W. A. Withington. Department of Geography, University of Kentucky.

1315 A geographic analysis of Kentucky Lake subdivisions. W. A. Franklin. Geography Department, Murray State University.

1330 Ad hoc market structure: the yard sale. Bill Daken. Geography Department, University of Louisville.

1345 A behavioral assessment of downtown space. Ann Dretzka. Graduate School of Public Affairs, Kentucky State University.

1400 Break.

1415 The development of cross-valley natural bridges in southeastern Ohio. Thomas C. Kind. Geography Department, Murray State University.

1430 Residential developer's locational decision and views on suburban versus exurban land development. Dinker Patel. Graduate School of Public Affairs, Kentucky State University.

1445 A probe of design development trends in Kentucky's gravity center: the Louisville, Lexington, Covington triangle. Ann Dretzka, Mark M. Chatfield, and Gaynelle R. Trevino. Graduate School of Public Affairs, Kentucky State University.

1500 Changing landuse patterns in Kentucky. Phillip Phillips. Department of Geography, University of Kentucky.

1515 Election of Officers.

Saturday, 20 November

0930–1230 Field trip in Lexington area.

GEOLOGY

Room 387, Chemistry–Physics Building
Charles T. Helfrich, Chairman, Presiding
Gary L. Kuhnhenn, Secretary

Friday, 19 November

1300 Petrographic and sulfur analysis of potential spoil from surface mining. P. W. Whaley, H. R. Clark, and V. P. Wiram. Department of Chemistry and Geology, Murray State University.

1315 Devonian to Mississippian stratigraphy and bone beds, east and west of the Cincinnati Arch in Kentucky, Indiana, Ohio, and Tennessee. J. E. Conkin. Department of Geology, University of Louisville, and B. M. Conkin. Jefferson Community College.

1330 Hydrology of the central Kentucky karst: summary of results of dye tracing and cave mapping. J. F. Quinlan and D. R. Rowe. Uplands Research Laboratory and Departments of Engineering Technology and Geography–Geology, Western Kentucky University.

1345 Relation of the "vein minerals" of Kentucky Mississippian, geodes to the Mississippi Valley stratiform ore deposits. I. S. Fisher. Department of Geology, University of Kentucky.

1400 Petrographic analysis of chert from the Paoli–Beaver Bend member of the Newman Limestone (Mississippian) of eastern Kentucky. T. P. Binkley. Department of Geology, Eastern Kentucky University (sponsored by H. P. Hodge).

1415 The relationship of sieve-size frequency distribution to thin-section (point-count) textural data. T. F. McLoughlin. Department of Geoscience, Morehead State University (sponsored by J. C. Philley).

1430 The rock cycle. R. J. Singh and J. Bushee. Department of Geology, Northern Kentucky University (sponsored by C. T. Helfrich).

1445 Stratigraphic correlation with multivariate analysis techniques. L. L. Chyi, L. Elizalde, and G. E. Smith. Institute for Mining and Minerals Research, University of Kentucky (sponsored by W. H. Dennen).

1500 The economic potential of the Devonian black shales in northeastern Kentucky. C. L. Sharpe II and G. E. Marshall. Department of Geoscience, Morehead State University (sponsored by J. C. Philley).

1515 Pyroclastic deposits in the Ordovician, Devonian, and Mississippian of Kentucky. J. E. Conkin. Department of Geology, University of Louisville, and B. M. Conkin. Jefferson Community College.

Saturday, 20 November

0930 Sectional meeting.

0945 Depositional environment of the Wilcox–Claiborne (Eocene) sediments in Henry,

Weakley, and Carroll counties, Tennessee. A. L. Clark. Department of Chemistry and Geology, Murray State University.

1000 UV-degradation of polymers. K. L. Gauri. Department of Geology. J. A. Gwinn and K. Popli. Department of Physics, University of Louisville.

1015 Additional findings concerning the megabrecchia at Jeptha Knob. C. R. Seeger. Department of Geography and Geology, Western Kentucky University.

1030 A simple means for correlation of parametric data sets. W. H. Dennen. Department of Geology, University of Kentucky.

1045 Clay mineralogy of the Pennington Formation of eastern Kentucky. G. Ellesworth. Kentucky Geological Survey (sponsored by H. P. Hodge).

1100 A depositional model for the Middle Ordovician Platteville Group, Lee and LaSalle counties, Illinois. G. L. Kuhnhenn. Department of Geology, University of Louisville.

1115 Preliminary paleomagnetic results from Upper Ordovician rocks of eastern Kentucky. T. Smith. Department of Geology, Eastern Kentucky University (sponsored by C. T. Helfrich).

1130 Our dwindling resources. L. Suranarayana. Kentucky Geological Survey.

1145 Coal *is* king in Kentucky. N. C. Kester. Department of Geology, Eastern Kentucky University.

1200 The Lexington Area Karst Project, an overview and some preliminary findings. J. Thrailkill and Michael R. McCann. Department of Geology, University of Kentucky.

PHYSICS

Room 287, Chemistry–Physics Building
David J. Boyle, KAPT President, Presiding
Charles D. Teague, Secretary

Friday, 19 November

1330 A mini-orange spectrometer for internal-conversion-electron measurement. Douglas E. Miracle and Bernard D. Kern. University of Kentucky.

1340 Positron studies of mercury–indium alloys. W. F. Huang and Y. C. Leung. University of Louisville.

1350 L-shell fluorescent yields (W_L) for Z=63 and Z=92. Christopher E. Laird. Eastern Kentucky University.

1400 Emission spectrum of mercury–gallium vapor mixture. Chilukuri Santarum. Union College.

1410 Beta decay of short lived nuclei near A=116 and A=190. Jesse L. Weil. University of Kentucky.

1420 Total cross section measurements for (p,n) and (α,n) reactions^{-27} AL. B. Hiller, K. K. Sekhauran, and F. Gabbard. University of Kentucky.

1430 Mossbäuer effects in methylcyclopentadienyl iron dicarbonyl dimer. T. C. Rinckel and D. J. Boyle. Thomas More College.

1450 Odd-Z, odd-N nuclei near mass number A=90. Bernard D. Kern. University of Kentucky.

Saturday, 20 November

0930 The effects of low-level exposures of X rays on the trained response of planaria. Adrian Gooch, Richard Buchanan, and William Buckman. Western Kentucky University.

0940 Radio recombination lines from the plane of the Milky Way. Andrew W. Seacorn. Northern Kentucky University.

0950 Survey of charge compensation of trivalent rare ions in BaF_2. W. J. Bresser, K. P. Roenker, and G. K. Miner. Thomas More College.

1000 Some iodine charge state measurements at 20 mev. Jana Godwin, Jill Crawford, Greg Bazzell, Ron Berkley, Russell Walker, Kenneth Courtney, Jack Brockman, and Lynn Bridwell. Murray State University.

1010 David Rittenhouse, scientist of 1776. Joel Gwinn. University of Louisville.

1020 The construction and use of a 6-inch Newtonian reflector in a photographic study of the moon. Mr. Jimmie Brownfield. Winner of KJAS competition in Physics.

1030 Air pollution levels of oxidants and nitrogen oxides in northern Kentucky. S. J. Schwartz and K. P. Roenker. Thomas More College.

1040 Use of a hand-held calculator in a science classroom. Dewey Moore. Owsley County High School.

1050 Experiences in solar heating. Michael R. McPherson. Northern Kentucky University.

1100 Mechanics of expressway traffic. R. A. Meier and J. E. Lang. Thomas More College.

1110 Study of barriers to expressway noise pollution. D. J. Simon and D. J. Boyle. Thomas More College.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY

Room 200, Funkhouser Building
Sanford L. Jones, Chairman, Presiding
Thomas P. Coohill, Secretary

Friday, 19 November

1315 Nonprotein amino acid modification of moth behavior and neuromuscular activity. Douglas L. Dahlman. Department of Entomology, University of Kentucky.

1330 Effects of canavanine, an arginine analogue, on reproduction and ovarial physiochemical composition of the moth, *Manduca sexta*. Ronald Palumbo and Douglas L. Dahlman. Department of Entomology, University of Kentucky.

1345 Noxious stimulation of the tooth pulp in awake cats: a behavioral study. Stephen

Wilson, John R. Meyer, and Kenneth H. Reid. Department of Physiology and Biophysics, University of Louisville.

1400 A comparison of apparent autonomic responses to routine dental procedures. G. A. West, A. E. Bastawi, and K. H. Reid. Department of Physiology and Biophysics, University of Louisville.

1415 An automated system for following reflex responsiveness over wide variations in excitability. G. Stege III, K. H. Reid, and S. Wilson. Department of Physiology and Biophysics, University of Louisville.

1430 Acupressure: noninvasive control of nocifensor reflex responsiveness in the awake cat. K. H. Reid and S. Wilson. Department of Physiology and Biophysics, University of Louisville.

1445 Biliary secretion and absorption of radioactive thyroxine glucuronide in *Rana catesbeiana* and *Chrysemys picta picta*. Sanford L. Jones. Department of Biological Sciences, Eastern Kentucky University.

1500 Prostoglandin E_2 and F_2 alpha synthesis in rat testis in vitro. Jai Sarup. Department of Biology, Murray State University.

Saturday, 20 November

0930 The effects of hypothalamic implants of prolactin on the onset of puberty in the female rat. James L. Voogt and Jay I. Levin. Department of Physiology and Biophysics, University of Louisville.

0945 Influence of carotid body sympathectomy on ventilatory response to hypoxia. J. Sewell and J. R. Meyer. Department of Physiology and Biophysics, University of Louisville.

1000 The influence of mammalian cell geometry on ultraviolet radiation sensitivity in the herpes virus-CV-1 cell system. Daniel J. Knauer and Thomas P. Coohill. Biophysics Laboratory, Western Kentucky University.

1015 Ultraviolet enhancement (Weigle reactivation) of irradiated herpes virus survival in mammalian cells. Thomas P. Coohill, Leslie James, and Sharon Moore. Biophysics Laboratory, Western Kentucky University.

1030 A fluorescent antibody assay for SV40 virus production in mammalian cells. Sharon P. Moore, Timothy J. Eichenbrenner, and Thomas P. Coohill. Biophysics Laboratory, Western Kentucky University.

1045 The identification of urinary glycosaminoglycans associated with angiosarcoma of the liver. Kevin L. Curran and Charles E. Kupchella. Cancer Center, University of Louisville.

1100 Carbon tetrachloride-induced changes in liver and urinary cyclosamino-gylcans in the rat. James Jarvis, Charles E. Kupchella, and Kevin L. Curran. Cancer Center, University of Louisville.

1115 Left ventricular diameter as an index of contractility in the closed chest dog. David W. Boone and William B. Wead. Department of Physiology and Biophysics, University of Louisville.

SCIENCE EDUCATION

Room 397, Chemistry–Physics Building
Ronald K. Atwood, Presiding
J. Truman Stevens, Secretary

Saturday, 20 November

0930 An evaluative study of a resource teacher implementation program in elementary science. Steve Henderson. Model Laboratory School, Eastern Kentucky University.

0950 Improving self-sufficiency of elementary science teachers. George H. Miller. Division of Natural Sciences, University of Louisville.

1010 Utilizing mass communications for in-service elementary science education: the system. Herbert N. Simmons. Science Education, Western Kentucky University.

1030 Utilizing mass communications for in-service elementary science education: the rationale and implications. Robert L. Stevenson. Science Education, Western Kentucky University.

1050 Science merit ratings. Frank Howard. State Science Consultant, State Department of Education.

1110 Performance of Kentucky high schools on the chemistry exam of the annual science and mathematics achievement program at Eastern Kentucky University. Darnell Salyer and Earl T. Crouch. Department of Chemistry, Eastern Kentucky University.

1130 Relationships among cognitive preferences, science processes and grade level for junior high students. Ronald K. Atwood and J. Truman Stevens. Science Education, University of Kentucky.

1150 Computer based resource units in environmental education. Terry Wilson. Environmental Consultant, State Department of Education.

1210 West Kentucky environmental education consortium. Shaw Blankenship. Environmental Education, Murray State University.

1230 Business Session.

PSYCHOLOGY

Room 359, Chemistry–Physics Building
Brent C. White, Chairman, Presiding
Don Brown, Secretary

Saturday, 20 November

1000 Sectional Business Meeting.

1015 The role of catecholamine synthesis in caffeine-induced hyperactivity. Brent C. White, Carol Clegg, and Eli Adams. Centre College.

1030 The role of perspective and slant in the perception of apparent size and distance. Jack G. Thompson and Claude A. Valenti. Centre College.
1045 Rambling remarks about some shortcomings of the statistical significance test for psychological investigations. James S. Calvin. University of Kentucky.
1100 Contrasting predictions of emotional processes derived from Leventhal's Parallel Processing Model, Epstein's Habituation Model, and Wicklund's Objective Self-awareness Theory. Donald H. Brown and Karen Haswell.
1115 Habituation of emotional responses. Anita Britton, Donald H. Brown, and Dave Horine.

SOCIOLOGY

Room 345, Chemistry–Physics Building
Robert L. Hoffelder, Chairman, Presiding
James S. Wittman, Jr., Secretary

Friday, 19 November

1300 Toward a theory of fertility. Dr. George. Murray State University.
1330 Social stratification: a comparative perspective. Henry H. B. Chang. Morehead State University.
1400 Changes in the modern Chinese family. Wai Kin Che. Campbellsville.
1430 Sectional Business Meeting. Elections of 1976–1977 Officers.

Saturday, 20 November

0945 Going steady as practiced by Kentucky high school students. James S. Wittman, Jr. Western Kentucky University.
1015 Television and the family: an overview of the Icelandic experience. Thomas P. Dunn. Western Kentucky University, and Bragi Josepsson. Republic of Iceland.

ZOOLOGY AND ENTOMOLOGY

Room 124, Funkhouser Building
Charles V. Covell, Jr., Chairman, Presiding
Henry H. Howell, Secretary

Friday, 19 November

1300 Business Meeting and Election of Officers.
1315 Efficiency and selectivity of two types of wood slat traps in Kentucky Lake. Ralph V. Jackson. Department of Biology, Murray State University.
1330 Age and growth of channel catfish, *Ictalurus punctatus*, in Dardanelle Reservoir, Arkansas. Thomas M. Freeze. Department of Biology. Murray State University.
1345 Some limnological parameters of Vickers Bay, Kentucky Lake. Kerry W. Prather. Department of Biology, Murray State University.
1400 Coniopterygidae of Kentucky. Victor Johnson and Paul H. Freytag. Department of Entomology, University of Kentucky.
1415 Coffee Break.
1430 Studies in artificial rearing of *Amblyseius fallacis*, a predator of the twospotted spider mite. Cary Patterson and J. G. Rodriguez. Department of Entomology, University of Kentucky.
1445 Preference and utilization of food by the coffee bean weevil, *Araecerus fasciculatus*. J. G. Rodriguez, M. F. Potts, and L. D. Rodriguez. Department of Entomology, University of Kentucky.
1500 Survivorship and life expectancy of *Drosophila melanogaster* population in abnormal oxygen-normal pressure regime. Gerrit P. Kloek, Gertrude C. Ridgel, and Dennis B. Ralin. Department of Biology, Kentucky State University.
1515 Ovipositional studies of *Bathyplectes anurus*, a parasitoid of the alfalfa weevil. Kenneth V. Yeargan and M. A. Latheef. Department of Entomology, University of Kentucky.

Saturday, 20 November

0945 A preliminary study of the benthic macroinvertebrates of the Bayou du Chien Creek in western Kentucky. James Roscher. Department of Biology, Murray State University.
1000 Lethal and teratogenic effects of inorganic mercury to the embryonic development of *Hyla gratiosa* Le Conte. Albert Westerman. Department of Biology, University of Kentucky.
1015 Genic variability and the adaptive strategy of periodical cicada (Homoptera: Magicicada). Dennis B. Ralin and Gerrit P. Kloek. Department of Biology, Kentucky State University.
1030 The effects of 2450 m Hz microwaves on *Rana pipiens*. Gordon Carnes, C. B. Hamann, and D. G. Puntenny. Department of Biology, Asbury College.
1045 The viral complex of the fall web worm, *Hyphantria cunea* (Drury), and related Arctiidae species. Drion G. Boucias and Gerald L. Nordin. Department of Entomology, University of Kentucky.
1100 Ultra low-volume spraying of Baygon for mosquito control. Gary Moneyham and Fred Knapp. Department of Entomology, University of Kentucky.
1115 The Society of Kentucky Lepidopterists: its contribution to our knowledge of Kentucky's butterflies and moths. Charles V. Covell, Jr. Department of Biology, University of Louisville.
1130 Comparative hematology in amphibians. Arland Hotchkiss. KJAS Winner of Zoology Section Award.

THE SIXTY-SECOND ANNUAL BUSINESS MEETING OF THE KENTUCKY ACADEMY OF SCIENCE UNIVERSITY OF KENTUCKY, LEXINGTON, KENTUCKY

19 and 20 November 1976

Hosts: Drs. Ellis V. Brown and William F. Wagner

MINUTES OF THE ANNUAL BUSINESS MEETING

The meeting was called to order by President Frederick Brown at 0805 in Room 139, Chemistry–Physics Building, with about 60 members in attendance.

After a motion by Secretary Prins and a second from the floor, the Minutes of the 1975 Annual Business Meeting at the University of Louisville, as recorded in TRANSACTIONS Vol. 37(1–2), were approved.

Secretary Prins then moved to accept all members that joined during 1975. Motion was seconded and carried.

Dr. Prins announced that membership has declined from 510 individual members in 1975 to 480 in 1976. The total mailing list includes about 580 entries in the computer at Western Kentucky University.

A moment of respect was given three individuals who passed away during the year: Dr. Robert Boyer, University of Kentucky; Dr. Lyle R. Dawson, University of Kentucky; and Dr. Morgan E. Sisk, Murray State University.

The Treasurer's Report was presented by Wayne Hoffman. The report was audited by Drs. R. L. Miller, D. H. Puckett, and E. O. Beal (Chmn), Western Kentucky University, and was found to be in exemplary form. Dr. E. V. Brown moved that the report be accepted. After a second, the motion carried. It was noted that the current issue of the TRANSACTIONS had not yet been paid for.

Treasurer's Report to Audit Committee
Kentucky Academy of Science
30 September 1975–11 November 1976

Cash in Citizens National Bank, Bowling Green, Kentucky		$ 5,347.27
RECEIPTS:		
Subsidy from State	$3,000.00	
Membership dues	2,038.50	
Annual Meeting	113.20	
Transactions subscriptions	344.50	
University of Louisville and other purchase of Transactions	1,087.00	
AAAS research grant	132.00	
Botany grant transfer	500.00	$ 7,215.20
		$12,562.47
DISBURSEMENTS:		
Botany grant	500.00	
Research grants	132.00	
Annual Meeting	234.75	
Publication of Transactions	4,129.16	
AAAS dues	24.50	
Stationery printing	11.23	
Miscellaneous	1.00	$ 5,032.64
		$ 7,529.83
Check to JKAS outstanding	500.00	
Cash in Citizens National Bank		$ 7,529.83
Savings Account, Lexington Federal Savings & Loan		$ 1,274.02
Botany grant		$ 890.96
Certificate of Deposit (Grant)		$ 2,641.68
TOTAL ASSETS:		$12,336.49

Dr. Brown next called for reports from the standing committees.

1. **Committee on Membership.** No report.

2. **Committee on Legislation.** This committee did not function because of activity of participants in the formation of the new standing committees (see below).

3. **Committee on Distribution of Research Funds** (Jerry Howell, Jr., Joe Winstead, Patricia Malik). Two recipients were announced for 1976:

a. Phyllis K. Lonneman, Simon Kenton High School, Independence, KY. $90.00 for a study on "Distribution of Odonata (Insecta) in Campbell, Boone, and Kenton counties."

b. Charles V. Covell, Jr., University of Louisville. $38.00 for continuing work on the "Lepidopteran Survey of the Red River Gorge."

4. **Committee on Publications.** Dr. Krumholz stated that from all indications the new format and regularity of issues of the TRANSACTIONS have been well received by the membership. However, increases in costs of printing will necessitate an increase in dues next year. Details of costs were outlined in a separate report in the Secretary's book (see below under New Business).

Reports of other committees were:

1. **Science Education Committee.** Dr. Ted George conveyed information relating to pupil weighting factors in science education, probably a dead issue; how fees for laboratory use are to be obtained by local schools now that it has been ruled unconstitutional to collect money from students; and other matters that the committee is keeping under close observation. More information about those matters will be forthcoming in subsequent NEWSLETTERS.

2. **Resolutions Committee.** Dr. Donald Batch submitted the following resolutions, which were unanimously accepted:

RESOLUTIONS

Whereas, the University of Kentucky has graciously served as the Host Institution for the Sixty-second Annual Meeting of the Kentucky Academy of Science, and whereas Dr. Ellis V. Brown and Dr. William F. Wagner, members of the Hospitality Committee, and other personnel of the University of Kentucky have all worked diligently to make the meeting a success and,

Whereas, the University of Kentucky has made outstanding contributions to scientific thought and leadership,

Therefore, be it resolved:

a. That the Kentucky Academy of Science express its appreciation to the University of Kentucky and the above individuals, and that the Academy's Secretary be instructed to so inform them.

b. That the Kentucky Academy of Science congratulate the University of Kentucky as an outstanding institution of higher education in Kentucky and our Nation and for the promotion of science through teaching, research, and public service.

3. **Board of Directors.** Dr. John C. Philley reported that two areas were considered seriously this year. Since the financial base of the Academy is of prime concern, the committee is actively pursuing means by which subsidies and/or grants can be obtained from state or private sectors. The primary reason for this is to enable the Academy to sustain publication of a quality journal.

The second matter related to recognition of a Distinguished Scientist in Kentucky. As a result, the Board initiated granting the first Distinguished Scientist Award. The recipient was Dr. Louis A. Krumholz, University of Louisville.

4. **The Junior Academy.** Dr. Herbert Leopold, Director, reported on activities of the Junior Academy ranging from periodic meetings to the establishment of a Science Days calendar. The Academy had an active year.

5. **AAAS Representatives.** No report.

Under Old Business, Dr. Brown recognized Dr. Joe Winstead concerning additional grant monies from an anonymous benefactor. Dr. Winstead announced that, in addition to the existing floristics grant, an annual amount of $2,000.00 will be added until a total of $10,000.00 has accumulated. From the interest, the Botanical Grant will be funded.

Dr. Brown then turned the attention of the Meeting to New Business.

The first matter related to Amendments in the Constitution to establish two new Standing Committees. The two proposed committees have been ad hoc committees for several years and warrant permanent status. Descriptions of the committees were read by the Secretary, and were considered separately as follows:

To add to Article VIII

From Section 1: There shall be four standing committees, namely:

To Section 1: There shall be six standing committees, namely: (and add) A **Committee on Public Science Education** consisting of five members of which four are appointed by the President, plus the Vice President *ex officio*. Of the appointed members, two are collegiate-level science teachers and two are subcollegiate science teachers, each serving three-year rotating terms. Chairperson is designated from the appointed members of the committee. It shall inform the Executive Committee and the Academy on actions taken by the officers of the Commonwealth of Kentucky on behalf of public science education and shall recommend to the Committee on Legislation appropriate action to be taken by the Academy.

A **State Governmental Science Advisory Committee** which includes the three *ex officio* positions of President, President Elect, and Past President; a member of the Board of Directors selected by that body; and three members of the Academy appointed by the President, to serve three-year rotating terms. Chairing this committee is the Past President. It shall bring to the attention of the Governor, appointed officials, and members of the Legislature science-related issues and concerns pertinent to the scientific community and to the people of the Commonwealth and shall seek to work in cooperation with those persons to resolve such scientific issues and concerns.

Dr. Donald Batch moved (Dr. John Meyer second) that the Committee on Public Science Education be established as a standing committee. Motion carried.

Dr. L. P. Elliott moved (Dr. H. Howell second) that the State Governmental Science Advisory Committee be established as a standing committee. Motion carried.

Dr. Brown recognized Editor Krumholz who discussed the need to raise dues. The present cost of one volume of the TRANSACTIONS is about $6.35 and dues are $6.00 per year. Although the matter of raising dues cannot be implemented until the next annual meeting, Dr. Krumholz requested a straw vote on whether or not the members would approve increasing annual dues to $10.00 for active members and to $6.00 for student members. There was general agreement for such an increase.

Dr. Brown commented that he hoped that some progress had been made during his year as President and that more publicity is needed to promote exposure of the Academy to Commonwealth officials. Perhaps a Publicity Officer would be appropriate. Dr. Brown announced that he will be leaving Kentucky shortly to accept a position

in the Psychology Department at The Pennsylvania State University, and expressed thanks to the Academy for his good experiences.

Dr. Brown then turned the meeting over to the Nominations Committee, Dr. J. G. Rodriguez (Chmn) (C. M. Dupier, Jr. and J. Meyer).

The new slate of officers was as follows:

President Elect: Charles E. Kupchella, University of Louisville

Vice President: Sanford L. Jones, Eastern Kentucky University

Secretary: Thomas Seay, Georgetown College

Treasurer: Bartlett G. Dickinson, Georgetown College

Members of the Board of Directors to 1980: Ivan Potter, Frankfort, and Gertrude C. Ridgel, Kentucky State University

The floor was opened for further nominations. Dr. E. V. Brown moved that nominations be closed and that the above slate be accepted by acclamation. After a second by T. Calhoon, the motion passed unanimously and the Secretary was ordered to declare the nominees elected by acclamation.

There being no further business, Dr. Charles Payne, incoming President, made a few remarks. He thanked the outgoing officers and announced that he would give priority attention to four areas: (1) promote increases in service of the Academy to the government and to scientists, (2) promote increases in Academy support for research, (3) promote increases in visibility of the Academy to the government and scientists, and (4) increase (or find) outside funding to subsidize the costs of Publishing the TRANSACTIONS.

With those comments, Dr. Payne adjourned the meeting at 0930.

Rudolph Prins, Secretary
Kentucky Academy of Science

NEWS AND COMMENT

President's Remarks It has been a good year! The Academy has moved forward during the past year, and is actively continuing its momentum in a number of important areas that will increase our service to the people of the Commonwealth in general and to members of the Academy specifically. This year, we will actively pursue increased support of scientific research and increased visibility of the Academy, its members, and, indeed, all members of the scientific establishment of Kentucky, especially science teachers at all levels.

The Academy will be able to increase scientific research in the coming year through generous donations of a dedicated scientist who continues to make anonymous contributions to the Academy for that purpose. There will be increased funds for distribution of research monies for floristic studies, because that same donor has established an endowment of $10,000 to be administered by the Academy for the "Kentucky Academy of Science Foundation for Botanical Research in Kentucky."

Dr. Ted George will maintain his dedicated activities and involvement in the public science education of Kentucky. To ensure proper science education to the youth of the Commonwealth, The Academy must continue to make its concerns and recommendations known to appropriate state organizations concerned with science education.

Another thrust of the Academy for the coming year will be to increase state support for publishing the *Transactions of the Kentucky Academy of Science.* Hopefully, the Government of the Commonwealth will recognize the Academy's contribution to the teaching of science and the support of research in Kentucky, and support the Academy in its many endeavors. I am certain that Dr. Marvin Russell will continue to be in the fore in this matter.

Fortunately for the Academy, Dr. Louis Krumholz will continue to serve as Editor of our *Transactions.* It is the dedication to the Academy of men like Dr. Krumholz that has made the Academy the success it is.

To all members of the Kentucky Academy of Science, I sincerely request your advice in matters the Academy should deal with this year, and I urge you to let me know if there is any way in which I and the Academy can be of service.

CHARLES PAYNE

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AIBS The American Institute of Biological Sciences (AIBS) has initiated an activity to increase the participation of biological scientists in all parts of the country in making decisions on public issues that involve biology. Much of that activity includes environmental issues that impinge on sciences of all disciplines. Representatives have been selected in each state to serve as contact persons, and Dr. Louis A. Krumholz has agreed to act in that capacity for Kentucky. He will be provided with information to be shared with his fellow scientists and other appropriate and interested persons on problems of air and water pollution, energy related problems, use of pesticides, Natural resources conservation, endangered species of plants and animals, and many other areas of concern. Anyone who wishes to obtain information, may contact Dr. Krumholz at the University of Louisville, Louisville, Kentucky 40208, or at his home in Louisville at 1214 Royal Avenue 40204.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and, once accepted, an attempt will be made to publish papers in the order of their acceptance. Manuscripts should be typed, double spaced throughout, on good quality white paper 8½ × 11 inches (216 × 279 mm). The original and one copy should be sent to the Editor and the author should retain a copy for his own use in correcting proof. Metric and Celsius units are to be used for all measurements instead of, or in addition to, English and Fahrenheit units. Format and style may vary somewhat depending on the scientific discipline, but the basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of papers in the Journals of the American Chemical Society, the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and A Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined.

The sequence of material in the manuscript should be: title page, abstract, body of the manuscript, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the author's name and address, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the body of the paper.

3. The body of the manuscript should include the following sections: Introduction, Acknowledgments (if applicable), Materials and Methods, Results, Discussion, Summary, and Literature Cited. In manuscripts of only a few pages, there is no need to break it up into sections, except for the Literature Cited. All tables and figures, as well as all literature cited must be referred to in the text.

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The Quality of Water Received as Precipitation on a Forested Watershed in Eastern Kentucky

MICHAEL T. SHEARER, GEORGE B. COLTHARP, AND ROBERT F. WITTWER
Department of Forestry, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

Precipitation can contain relatively high concentrations of various minerals that may influence both surface water quality and plant growth. Forest canopies frequently alter the chemical characteristics of rainfall passing through them. Precipitation was sampled in the open, under hardwoods, and under pine in eastern Kentucky in late summer 1975. Levels of nitrate and magnesium were slightly lower than others have reported, but sulfate, calcium, and sodium were much higher. All rainfall samples were acidic, and precipitation collected under the pine canopy contained greater concentrations of nitrate nitrogen, sulfate, and calcium, while that collected from beneath hardwood canopies contained greater concentrations of magnesium, potassium, and sodium.

INTRODUCTION

Contamination of water does not always begin after it reaches the earth's surface. Rainwater can contain concentrations of various minerals high enough to influence both surface water quality and plant growth.

A recent article in the Lexington Leader reported that Kentucky is one of 24 eastern states experiencing high sulfate pollution resulting in acid rainfalls and health threats (Martin 1975). The chief cause was reported to be emission of sulfur dioxide by coal burning power plants.

Elements in precipitation can also influence the growth of plants. The content of nitrogen, calcium, magnesium, potassium, and other essential elements in rain may have noticeable effects on the nutrient cycles for many areas (Ingham 1950).

This preliminary report on the quality of precipitation is part of an overall study of nutrient budgeting on a forested watershed in eastern Kentucky.

BACKGROUND

Plant nutrient additions in rainfall have interested researchers for many years. Comparison of results reported by past investigations, though, presents several difficulties. First, the observed mineral content of rainfall is influenced by the collection method. Samples can include precipitation only, or they may include dry fallout as well. This combination is termed bulk precipitation (Hem 1970). Leaving collection devices continually open or open just during precipitation events determines which is sampled. Sampling errors are more probable when the containers remain open for long periods of time. Contamination can occur from bird droppings, localized airborne soil particles, and insects, leaves, and twigs. Nitrogen compounds

TABLE 1.—AVERAGE VALUES OF SELECTED CHEMICAL CONSTITUENTS OF PRECIPITATION RECEIVED ON ROBINSON FOREST FROM 18 AUGUST THROUGH 18 OCTOBER 1975 AT EACH OF 3 LOCATIONS. ALL VALUES ARE IN MG/L EXCEPT pH

Constituent	Location								
	Open		Pine	Hardwood canopy					
	(1)	(2)	(1)	(1)	(2)	(3)	(4)	(5)	Avg.
pH	4.70	5.06	4.04	6.39	6.23	5.66	6.20	4.91	
NO_3–N	0.22	0.46	2.03	0.29	0.13	0.26	0.61	0.39	0.55
SO_4^{--}	10.83	8.23	19.92	7.11	8.17	8.66	12.20	15.90	11.38
Ca^{++}	1.75	1.51	5.34	4.03	3.18	2.47	4.53	4.63	3.43
Mg^{++}	0.12	0.09	0.45	0.55	0.49	0.28	0.77	1.02	0.47
Na^{+}	3.51	3.37	3.91	4.49	4.23	4.14	4.32	3.64	3.95
K^{+}	0.24	0.33	1.15	1.93	2.23	2.15	4.85	4.94	2.23

may also change form or be lost (Eriksson 1952).

Additionally, variation in rainfall composition is inherent due to the conditions that cause precipitation, that is, the mixing of several air masses. Variation occurs from place to place, storm to storm, and within a single storm (Hem 1970).

There are various sources of mineral elements in rainfall. Sulfur can arise from particulate sources, such as soil dust, sea salt, or fertilizers, or gaseous sources, such as fossil fuel combustion, industrial processes, anaerobic decay of organic matter, and volcanic activity. Gaseous sources are dominant, as evidenced by sulfate concentrations remaining high throughout even long storms, where particulate sources would be reduced by washout (Gambell and Fisher 1966). Coal burning is the chief source of atmospheric sulfur (Junge and Werby 1958), and the concentration may become highest in stagnant air masses of summer and autumn (Gambell and Fisher 1966). This may influence rainfall patterns, since sulfate ions are important condensation nuclei (Junge and Werby 1958), and the concentration may become highest in stagnant air masses of summer and autumn (Gambell and Fisher 1966).

Unlike sulfate, the nitrate nitrogen content of precipitation does not seem to stem from human activities. There is apparently no strong influence from the industrial areas of the northeastern United States (Junge 1958). The gaseous sources of nitrate nitrogen, primarily ammonia and nitrogen dioxide in the atmosphere, predominate, rather than particulate matter (Ingham 1950, Gambell and Fisher 1966).

Calcium, magnesium, potassium, and to some extent, sodium in the atmosphere are derived primarily from soil dust (Gambell and Fisher 1966).

A number of investigators studying nutrient cycling have reported changes in the

TABLE 2.—AVERAGE VALUES OF SELECTED CHEMICAL CONSTITUENTS OF PRECIPITATION RECEIVED ON ALL STUDY SITES ON ROBINSON FOREST FROM 18 AUGUST THROUGH 18 OCTOBER 1975 DURING 7 STORMS. ALL VALUES IN MG/L EXCEPT pH. ND = NO DATA

Storm	Constituent							ppt. (cm.)
	pH	NO_3–N	SO_4^{--}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
18 Aug	4.86	0.65	23.50	4.70	0.51	4.40	2.60	0.51
12 Sep	5.27	0.11	7.62	1.86	0.16	3.72	0.95	5.33
24 Sep	4.89	0.18	4.39	2.06	0.17	3.73	1.20	3.30
2 Oct	4.80	1.92	16.98	5.75	1.19	4.29	5.11	0.69
9 Oct	5.70	0.43	9.77	nd	nd	nd	nd	0.51
17 Oct	5.73	0.36	8.25	2.76	0.37	3.19	1.64	5.51
18 Oct	6.35	0.20	7.23	2.93	0.35	4.41	1.33	0.81

TABLE 3.—COMPARISON OF IONIC VALUES IN RAINFALL IN KENTUCKY DURING THE LATE SUMMER OF 1975 WITH THOSE FROM OTHER STUDIES

Constituent	Kentucky 1975 (open)	Kentucky[1] 1922	Illinois[2] 1970–1971	Carolina–Virginia[3] 1962–1963	New Hampshire[4] 1964–1966	East Central USA[5]	USA Summary[6]	Sweden[7] 1950
NO_3–N	0.34	0.74	0.76	0.62	1.06	nd	0.46	nd
SO_4^{--}	9.53	nd[8]	nd	2.18	3.20	2.04	2.84	nd
Ca^{++}	1.63	nd	<1.40	0.65	nd	0.65	0.81	0.49
Mg^{++}	0.10	nd	<0.30	0.14	nd	nd	0.56	nd
Na^{+}	3.44	nd	nd	0.56	nd	0.25	2.20	0.60
K^{+}	0.29	nd	<1.86	0.11	nd	0.11	0.17	0.32

[1] Eriksson 1952. [2] Miceli et al. 1975. [3] Gambell and Fisher 1966. [4] Fisher et al. 1968. [5] Junge 1958. [6] Hem 1970. [7] Tamm 1951. [8] nd = no data.

mineral composition of rainwater dripping through a forest canopy. Greater amounts of calcium, magnesium, and potassium cations were found under tree crowns than in open areas, but differences in nitrogen content were variable (Tamm 1951, Madgwick and Ovington 1959, Voight 1960, Azevedo and Morgan 1974, Miceli et al. 1975).

SAMPLING SYSTEM

The study area for this project, the University of Kentucky's Robinson Forest, is in Breathitt County, in the mountainous eastern portion of the state. Several large coal strip-mining operations are in the vicinity, one within a mile (1.609 km) of the experimental watershed and in the direction (west) from which the prevailing winds blow. There are no coal-fired power plants in the immediate area, but those in the eastern counties of Pulaski, Bell, Mercer, Clark, and Woodford, and likely even the large plants in central and western Kentucky and Tennessee may influence precipitation quality.

Polyethylene funnels on glass bottles were set at 8 stations in the area. Five stations were under hardwood forest, 1 under pine, and 2 in open areas, which is roughly proportional to the areal extent of each cover type. The hardwoods were representative of the eastern mixed hardwood forest type which is characterized by species such as *Quercus* spp., *Carya* spp., *Acer* spp., *Fagus* spp., *Liriodendron tulipifera*, etc., and the pine was *Pinus virginiana*. The collection devices were opened only during precipitation events, so dry fallout was excluded from the samples. The samples were collected after the rain and were frozen, to inhibit biological alteration of nitrogen compounds. In the laboratory, sulfate determinations were made by visible spectrophotometry, cations by atomic absorption spectrophotometry, and nitrate

TABLE 4.—COMPARISON OF CHANGES IN COMPOSITION OF RAINFALL IN THE OPEN AND UNDER PINE TREES DURING LATE SUMMER 1975 IN KENTUCKY WITH THOSE REPORTED IN 3 OTHER STUDIES

Constituent	Studies							
	Kentucky 1975		Illinois 1970–1971[1]		Sweden 1950[2]		Connecticut[3]	
	Open	Pine	Open	Pine	Open	Pine	Open	Pine
NO_3–N	0.34	2.03	<0.76	0.76	nd	nd	nd	nd
SO_4^{--}	9.53	19.92	nd[4]	nd	nd	nd	nd	nd
Ca^{++}	1.63	5.34	<1.40	3.13	0.49	2.80	0.70	1.60
Mg^{++}	0.10	0.45	<0.30	0.61	nd	nd	nd	nd
Na^{+}	3.44	3.91	nd	nd	0.60	5.10	nd	nd
K^{+}	0.29	1.15	<1.86	2.84	0.32	3.37	0.45	1.15

[1] Miceli et al. 1975. [2] Tamm 1951. [3] Voigt 1960. [4] nd = no data.

TABLE 5.—COMPARISON OF CHANGES IN COMPOSITION OF RAINFALL IN THE OPEN AND UNDER A MIXED HARDWOOD STAND DURING THE LATE SUMMER OF 1975 IN KENTUCKY WITH THOSE REPORTED FOR CONNECTICUT

	Studies			
	Kentucky 1975		Connecticut[1]	
Constituent	Open	Mixed hardwood	Open	Beech
NO_3–N	0.34	0.35	nd[2]	nd
SO_4^{--}	9.53	9.45	nd	nd
Ca^{++}	1.63	3.74	0.70	1.30
Mg^{++}	0.10	0.62	nd	nd
Na^{+}	3.44	4.16	nd	nd
K^{+}	0.29	3.17	0.45	1.10

[1] Voigt 1960. [2] nd = no data.

by reduction and colorimetry. All analyses were conducted according to standard methods (Amer. Publ. Health Ass. 1971).

RESULTS

Average values of the parameters measured at each sampling location are listed in Table 1. The precipitation received under pine foliage contained the highest concentration of sulfate and nitrate, and was the most acidic. Cations were generally higher on the forested sites than in the open areas.

Averages for each storm are shown in Table 2. The storms of 18 August and 2 October 1975 generally had the highest ion concentrations, and those storms were among the lowest in total precipitation. The same effect was also noticed in England, where high concentrations of potassium, calcium, magnesium, and phosphorus were associated with low rainfall amounts (Madgwick and Ovington 1959).

Data for all parameters were highly variable, particularly nitrate and sulfate. Nitrate nitrogen concentrations ranged from 0 to 8.00 mg/l, and sulfate levels ranged from 2.10 to 57.80 mg/l.

The pH values of rainfall samples were generally low under the pine canopy, while under hardwood foliage they had a more neutral reaction than open plots. The average rainfall pH at the pine site was 4.00, with a low of 3.00 and a high of 4.60. The average pH under hardwoods was 6.10, ranging from 5.00 to 7.20. The average pH for open plots was 4.90, slightly lower than the 5.20 reported for North Carolina and Virginia (Gambell and Fisher 1966).

Ionic concentrations of the eastern Kentucky samples are compared with those from other investigations in Table 3. Nitrate nitrogen values in our study were lower, while sulfates were much higher. Part of this effect may be due to the time difference, since more fossil fuels are burned now than 10 or more years earlier.

Differences in average composition between open and forested plots are presented in Tables 4 and 5, for eastern Kentucky and other study areas. In this study, ionic levels of rainfall were generally higher after moving through pine foliage. The same trend was shown in the other reports (Tamm 1951, Madgwick and Ovington 1959, Voigt 1960, and Azevedo and Morgan 1974), except that nitrate nitrogen levels in Illinois were not greatly affected. Differences in crown characteristics among various species of pine affect the proportion of rainfall intercepted, passed as throughfall, or passed as stemflow, and this can influence nutrient movement in precipitation (Miceli et al. 1975).

Rainfall collected under hardwood foliage contained high concentrations of calcium, magnesium, and potassium, but sulfate and nitrate levels were apparently unchanged. These data were collected late in the growing season while the foliage was still on the trees. However, enrichment of rainfall may occur to some extent in hard-

woods even during the dormant season, due to the influence of tree branches (Madgwick and Ovington 1959).

Mineral additions to precipitation by forest canopies occur by leaching of nutrients from leaves and branches, and by the washing off of dust particles from the surfaces. In this area, washing of dust is likely the dominant source.

SUMMARY AND CONCLUSIONS

The mineral content of precipitation in Robinson Forest was high when compared to values derived in other studies. Nitrate nitrogen and magnesium were slightly lower, while sulfate, calcium, and sodium were much higher. The low pH values indicate that precipitation in the region is acidic.

We cannot provide a definitive explanation for the relatively high mineral values and low pH obtained in this preliminary study, but since the nearby strip-mining operations produce large amounts of dust during dry periods, it seems logical that this material could find its way back to earth in precipitation.

LITERATURE CITED

AMERICAN PUBLIC HEALTH ASSOCIATION. 1971. Standard methods for the examination of water and wastewater. 13th Ed. Washington, D. C. 874 pp.

AZEVEDO, J., AND D. L. MORGAN. 1974. Fog precipitation in coastal California forests. Ecology 55:1135–1141.

ERIKSSON, E. 1952. Composition of atmospheric precipitation. I. Nitrogen compounds. Tellus 4:214–232.

FISHER, D. A., A. W. GAMBELL, G. E. LIKENS, AND F. H. BORMANN. 1968. Atmospheric contributions to water quality of streams in the Hubbard Brook Experimental Forest, New Hampshire. Water Resourc. Res. 4: 1115–1126.

GAMBELL, A. W., AND D. A. FISHER. 1966. Chemical composition of rainfall in eastern North Carolina and southeastern Virginia. U.S. Geol. Surv. Water-Supp. Pap. 1535-K. 41 pp.

HEM, J. D. 1970. Principles and processes controlling composition of natural water. Pp. 12–40. *In* J. D. Hem (Ed.). Study and interpretation of the chemical characteristics of natural water. U.S. Geol. Surv. Water-Supp. Pap. 1473. 358 pp.

INGHAM, G. 1950. The mineral content of air and rain and its importance to agriculture. J. Agric. Sci. 40:55–61.

JUNGE, C. E. 1958. The distribution of ammonia and nitrate in rain water over the United States. Trans. Amer. Geophys. U. 39: 241–248.

———, AND R. T. WERBY. 1958. The concentration of chloride, sodium, potassium, calcium, and sulfate in rain water over the United States. J. Meteorol. 15:417–425.

MADGWICK, H. A., AND J. D. OVINGTON. 1959. The chemical composition of precipitation in adjacent forest and open plots. Forestry 32: 14–22.

MARTIN, M. 1975. Recent EPA report says Kentucky experiencing high sulfate pollution. The Lexington Leader, 26 September, D-1.

MICELI, J. C., G. L. ROLFE, L. E. ARNOLD, AND W. R. BOGGESS. 1975. A preliminary study of the role of precipitation in nutrient cycling in loblolly (*Pinus taeda* L.) and short leaf pine (*Pinus echinata* Mill.) pine plantations. Univ. Ill. (Champaign–Urbana) Agric. Exp. Sta., For. Res. Pap. 75-5. 4 pp.

TAMM, C. O. 1951. Removal of plant nutrients from tree crowns by rain. Physiol. Plant. 4: 184–188.

VOIGT, G. K. 1960. Alteration of the composition of rainwater by trees. Amer. Midl. Nat. 63:321–326.

The Aquatic Fauna of Russells Chapel Spring, Calloway County, Kentucky

KATHY J. RAYBURN AND THOMAS M. FREEZE
Department of Biological Sciences, Murray State University, Murray, Kentucky 42071

ABSTRACT

A survey of the aquatic fauna of Russells Chapel Spring in Calloway County, Kentucky, yielded the following kinds of organisms: 4 protozoans, 22 macroinvertebrates, 6 fishes, 2 amphibians, and 1 reptile. The collection includes a specimen of the rare aquatic earthworm *Haplotaxis gordioides*.

INTRODUCTION

Little information is available in the literature concerning the ecology of temperate springs in Kentucky. The most extensive work reported is a series of studies on the spring stream of Doe Run in Meade County in north-central Kentucky by Cole and Minckley (1961), Krumholz (1967), Minckley (1961, 1963), Minckley and Cole (1963), Minckley and Tindall (1963), Prins (1964, 1968), Walker (1961), and others. Minshall (1967, 1968) made a detailed study of Morgan's Creek, Meade County, Kentucky. A statewide ecological survey of Kentucky's temperate springs is needed as each spring is a unique microhabitat. Because of the uniform conditions often encountered, many species may be present in springs far outside their normal geographical range or a spring may harbor relict species, phreatics, or crenobionts (Hynes 1976). This paper reports a survey of the aquatic fauna of a temperate spring, Russells Chapel Spring, in Calloway County, Kentucky.

ACKNOWLEDGMENTS

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DESCRIPTION OF STUDY SITE

Russells Chapel Spring rises in Calloway County, Kentucky, near a dirt road 100 m south of Russells Chapel, 36° 40′ N and 88° 07′ W. The boil is 3 m across with a maximum depth of 1 m. The water bubbles up from a central basin composed of unstable sand surrounded by clay sediment, and gives rise to a small stream choked with vegetation that empties into Little Sugar Creek approximately 30 m from the spring. Little Sugar Creek empties into the Blood River Embayment on the western side of Kentucky Lake (Tennessee River).

The surrounding area is low lying and composed of soils of the Bodine cherty silt loam and Iuka silt loam types (Humphrey et al. 1973). The area is poorly drained with numerous stagnant pools spaced throughout. Tulip poplar *Liriodendron tulipifera* trees dominate the surrounding rich woods.

Geologically, Calloway County is a part of the northern extension of the eastern Gulf Coastal Plain and contains the most recent geologic formation in Kentucky. During the Cretaceous, Tertiary, and Quaternary periods, Mississippian deposits were covered with gravel, sand, silt, and clay. The formations have not yet consolidated into sandstone or shale (Humphrey et al. 1973).

MATERIALS AND METHODS

Since Russells Chapel Spring represents a microhabitat in a state of delicate bal-

ance, it was decided to limit collections to a single period on 22–24 June 1976. On 23 June, an Ekman dredge, 150 × 150–mm opening, was used to sample 2 sites for benthic macroinvertebrates, the boil proper and midway along the stream, approximately 10 m from the boil. In the boil proper, 5 bottom samples were taken (1 from the unstable sand center and 4 from the perimeter) while a single sample was taken from the stream. Each sample consisted of 3 grabs with the Ekman dredge. On the night of 23 June, a drift net was placed in the stream and left for 12 hours. On 24 June, samples of fishes, amphibians, and invertebrates inhabiting stands of vegetation were collected using an electric shocker and dip nets of various meshes. Representative specimens of the fishes, amphibians, and reptiles were fixed in 5 percent formalin and preserved in 40 percent isopropyl alcohol, and all macroinvertebrates were fixed and preserved in 40 percent isopropyl alcohol. Two 500–ml water samples were taken and examined for Protozoa.

Organisms were identified upon return to the laboratory at Murray State University. In addition, macroinvertebrates were counted, and an index of diversity computed at the generic level using the machine formula of Weber (1973). Since this was basically a qualitative study, temperature was the only physical parameter measured.

Results and Discussion

This survey resulted in the collection of 4 species of Protozoa, 22 species of macroinvertebrates, 6 species of fishes, 2 species of amphibians, and 1 species of reptile. In the following listing, the scientific name is followed where applicable by the common name, collection site, and notes on the distribution and abundance of each species. Species were ranked arbitrarily as rare when fewer than 10 organisms were collected, as common when 10–100 organisms were collected, and as abundant when more than 100 specimens were taken. The nomenclature and arrangement of taxa are those of Pennak (1953), Eddy and Hodson (1961), Bailey et al. (1970), and Kudo (1971).

The Fauna

Protozoans

CHLOROMONADIDA
- Chlamydomonadidae
  - *Chlamydomonas globosa.* Boil.

EUGLENOIDIDA
- Euglenidae
  - *Trachelomonas volvacina.* Boil.
  - *T. hispida.* Boil.

TESTACIDA
- Difflugidae
  - *Difflugia globosa.* Boil.

Macroinvertebrates

OPISTHOPORA
- Lumbriculidae
  - *Lumbriculus inconstans,* aquatic earthworm. Stream. Rare.
  - *Rhynchelmis* sp. Boil and stream. Common.
- Haplotaxidae
  - *Haplotaxis gordioides.* Stream. Rare.

ISOPODA
- Asellidae
  - *Lirceus fontinalis,* aquatic sowbug. Boil and stream. Common.
  - *Asellus stygius,* aquatic sowbug. Boil. Rare.

AMPHIPODA
- Gammaridae
  - *Crangonyx* sp., scud. Boil and stream. Abundant.

DECAPODA
- Astacidae
  - Subfamily Cambarinae (immature specimens prevented further classification), crayfish. Boil and stream. Rare.

EPHEMEROPTERA
- Baetidae
  - *Caenis* sp., mayfly. Boil. Rare.

ODONATA
- Agrionidae
  - *Agrion* sp., damselfly. Boil. Rare.

HEMIPTERA
- Hydrometridae
  - *Hydrometra* sp., marsh treader. Boil. Rare.

Gerridae
Gerris sp., water strider. Boil. Common.
Veliidae
Velia sp., broad-shouldered water strider. Boil. Rare.
Notonectidae
Notonecta sp., back swimmer. Boil. Common.
Corixidae
Genus unidentifiable as specimens were female, water boatman. Boil. Common.

MEGALOPTERA
Sialidae
Sialis sp., alderfly. Boil and stream. Common.
Corydalidae
Chauliodes sp., dobsonfly. Stream. Rare.

TRICHOPTERA
Molannidae
Molanna sp., caddisfly. Stream. Rare.

COLEOPTERA
Haliplidae
Peltodytes sp., crawling water beetle. Boil. Rare.
Helodidae
Elodes sp. Stream. Rare.

DIPTERA
Tipulidae
Tipula sp., cranefly. Stream. Rare.
Limnophila sp., cranefly. Stream. Rare.
Chironomidae
Pentaneura sp., midge. Stream. Rare.
Tendipes sp., midge. Boil and stream. Abundant.
Ceratopogonidae
Palpomyia sp., biting midge. Boil and stream. Common.
Tabanidae
Chrysops sp. Boil. Rare.

Fishes

PETROMYZONTIFORMES
Petromyzontidae
Genus unidentified (larval specimens), lamprey. Boil and stream. Common.

CYPRINIFORMES
Cyprinidae
Campostoma anomalum, stoneroller. Boil. Common.
Chrosomus erythrogaster, southern redbelly dace. Boil. Rare.
Semolitus atromaculatus, creek chub. Boil. Common.
Catostomidae
Erimyzon oblongus, creek chubsucker. Boil. Common.

PERCIFORMES
Percidae
Etheostoma caeruleum, rainbow darter. Boil. Common.
E. squamiceps, spottail darter. Boil. Common.

Amphibians

SALAMANDROIDEA
Plethodontidae
Desmognathus fuscus, dusky salamander. Boil. Common.

ANURA
Ranidae
Rana pipiens, leopard frog. Boil. Common.

Reptiles

Testudinidae
Chrysemys scripta elegans, red-eared turtle. Boil. Rare.

A generic diversity of 2.24 was calculated for the benthic macroinvertebrates from the stream while the boil itself exhibited a diversity of 2.27. These values indicate a relatively undisturbed environment having large numbers of genera with no individual genus present in overwhelming abundance (Weber 1973).

Mature specimens of *Haplotaxis gordioides* have never been identified for certain from North America but immature worms resembling it have been found in a few locations (Brinkhurst and Jamieson 1971). The exact identity of all these immature individuals must remain in doubt until the variation pattern of the dorsal setae of mature *H. gordioides* is documented (Cook 1975). The specimen collected, although immature, was identified as *Haplotaxis* on the basis of the large prostomium with a

transverse groove and the unusual sickle-shaped setae in the ventral bundles and the identification was later verified by Dr. R. O. Brinkhurst. The single specimen collected at Russells Chapel Spring probably is indicative of an association between the spring and subterranean waters since *Haplotaxis gordioides* has been found associated with subterranean waters in England, most of continental Europe, Japan, and rarely in North America (Cook 1975).

Asellus stygius is a blind isopod that inhabits subterranean springs, wells, and caves in Missouri, Indiana, and Kentucky and is rarely encountered in surface waters (Pennak 1953). However, Minckley (1961) reported it from several spring streams in north-central Kentucky.

The 2 most abundant macroinvertebrates encountered were amphipods and chironomids. The genus *Crangonyx* is widely distributed and common in unpolluted clear waters including springs, spring brooks, streams, pools, ponds, and lakes (Pennak 1953). Chironomids are considered cosmopolitan.

The collection of the southern redbelly dace, *Chrosomus erythrogaster*, represented the first collection of this species in the Coastal Plain region of western Kentucky (Freeze and Rayburn 1977).

LITERATURE CITED

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. A list of common and scientific names of fishes from the United States and Canada. (3rd ed.). Spec. Publ. No. 6, Amer. Fish. Soc., Washington, D. C. 150 pp.

BRINKHURST, R. O., AND B. G. JAMIESON. 1971. Aquatic Oligochaeta of the world. Oliver and Boyd, Edinburgh, Scotland. 860 pp.

COLE, G. A., AND W. L. MINCKLEY. 1961. A new species of amphipod crustacean (genus *Gammarus*) from Kentucky. Trans. Amer. Microsc. Soc. 8:391–398.

COOK, D. G. 1975. Cave-dwelling aquatic Oligochaeta (Annelida) from the eastern United States. Trans. Amer. Microsc. Soc. 94(1): 24–37.

EDDY, S., AND A. C. HODSON. 1961. Taxonomic keys to the common animals of the north central states. Burgess Publ. Co., Minneapolis, Minn. 162 pp.

FREEZE, T. M., AND K. J. RAYBURN. 1977. A note on the distribution of *Chrosomus erythrogaster* (Cyprinidae) in Kentucky. Trans. Ky. Acad. Sci. 38(1–2):97.

HUMPHREY, M. E., F. L. ANDERSON, R. A. HAYES, AND J. D. SIMS. 1973. Soil survey of Calloway and Marshall Counties, Kentucky. U. S. Govt. Print. Off. Washington, D. C. 82 pp.

HYNES, H. B. N. 1976. The ecology of running waters. Univ. Toronto Press, Toronto, Can. 555 pp.

KRUMHOLZ, L. A. 1967. Accumulation of radioactive fallout materials in the biota of Doe Run, Meade County, Kentucky, 1959–1963. Pp. 791–818. *In* B. Åberg and F. P. Hungate (Eds.). Radioecological Concentration Processes. Pergamon Press, New York, N.Y. 1040 pp.

KUDO, R. R. 1971. Protozoology. Charles C Thomas, Springfield, Ill. 1173 pp.

MINCKLEY, W. L. 1961. Occurrence of subterranean isopods in the epigean environment. Amer. Midl. Nat. 66:452–455.

———. 1963. The ecology of a spring stream Doe Run, Meade County, Kentucky. Wildl. Monogr. No. 11:1–124.

———, AND G. A. COLE. 1963. Ecological and morphological studies on gammarid amphipods (*Gammarus* spp.) in spring-fed streams of northern Kentucky. Occ. Pap. C. C. Adams Cent. Ecol. Stud. No. 10:1–35.

———, AND D. R. TINDALL. 1963. Ecology of *Batrachospermum* sp. (Rhodophyta) in Doe Run, Meade County, Kentucky. Bull. Torrey Bot. Club 90(6):391–400.

MINSHALL, G. W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48(1): 139–149.

———. 1968. Community dynamics of the benthic fauna in a woodland springbrook. Hydrobiologia 32(3–4):305–339.

PENNAK, R. W. 1953. Fresh-water invertebrates of the United States. The Ronald Press Co., New York, N. Y. 769 pp.

PRINS, R. 1964. *Attheyella carolinensis* Chappuis (Copepoda: Harpacticoida) on freshwater crayfishes from Kentucky. Trans. Amer. Microsc. Soc. 83(3):370–371.

———. 1968. Comparative ecology of the crayfishes *Orconectes rusticus* and *Cambarus tenebrosus* in Doe Run, Meade County, Kentucky. Int. Rev. Ges. Hydrobiol. 53(5):667–714.

WALKER, B. A. 1961. Studies on Doe Run, Meade County, Kentucky, IV. A new species of isopod crustacean (genus *Asellus*) from Kentucky. Trans. Amer. Microsc. Soc. 80: 385–389.

WEBER, C. (Ed.). 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. National Environmental Res. Center. Environmental Protection Agency. Cincinnati, O. 176 pp.

The Occurrence and Relative Abundance of Planktonic Fish Larvae in Anderson Creek Embayment, Kentucky Lake, Kentucky

Wayne L. Davis and Thomas M. Freeze
Department of Biological Sciences, Murray State University, Murray, Kentucky 42071

Abstract

Larval fishes were collected from Anderson Creek embayment of Kentucky Lake with a 0.8-mm mesh plankton net and habitat seine to document the species of fishes utilizing the area as a spawning ground. The Clupeidae constituted 99.6 percent of the total catch while other species made up the remaining 0.4 percent. As the water temperature rose above 19.0 C, a sharp increase occurred in the total number of Clupeidae. The nonclupeid fishes were represented by *Morone* sp. (above 17.0 C) and by *Pomoxis* sp. (between 19.0 and 22.0 C).

Introduction

The Anderson Creek embayment of Kentucky Lake has been a center of considerable interest since 1973 due to the impending industrialization of a portion of its shoreline. To determine the impact of such a development on the aquatic environment, 2 studies were conducted on the physical, chemical, and biological parameters of the embayment by Crowell (1974, unpublished master's thesis, Murray State University, Murray, Kentucky) and Kinman (1976, unpublished master's thesis, Murray State University, Murray, Kentucky). A parallel study was conducted on the Vickers Creek embayment of Kentucky Lake by Prather (1977, unpublished master's thesis, Murray State University, Murray, Kentucky) to serve as a comparison for the industrialization on Anderson Creek embayment.

To supplement the findings of those investigations on water quality, plankton, and benthic macroinvertebrates, the present study was initiated to determine which fishes utilized Anderson Creek embayment as a spawning ground. According to Marcy (1976), larval fishes usually are planktonic or free floating at various stages of their development and must depend upon current for dispersal. Thus, they are poorly adapted for avoiding hazardous environmental conditions that might arise from intense constructional practices or industrial accidents. If such hazardous environmental conditions should occur, it is extremely important to be able to assess not only the immediate but the long-range effects upon the ecosystem. The data gathered during this investigation can serve as an important reference should the need arise for such an assessment of Anderson Creek embayment.

Description of Area

Anderson Creek embayment is on the western side of Kentucky Lake at Tennessee River Mile (TRM) 45.5. The embayment is formed by Anderson Creek, a third order stream according to the classification of Kuehne (1962). Anderson Creek and its headwaters drain primarily woodlands with very little agricultural activity in the area. The embayment itself is 109.4 m (359.0 feet) above the sea level; has a mean depth of 4.8 m (15.6 feet); a shoreline of 3.9 km (2.4 miles); and a surface area of 0.71 km^2 (177 acres) according to Crowell (unpublished thesis). Extensive shallow areas are present at the upper end of the bay.

Materials and Methods

Air and surface water temperatures were taken during each sampling trip with a standard mercury thermometer. Secchi disk readings were recorded following the procedure outlined by Hutchinson (1956).

Larval fishes were collected with a cone-shaped, 0.5-m diameter net equipped with 0.8-mm netting and a 354.5-ml (12 oz)

collection cup attached to the cod end of the net. The net was towed with a 15-m braided nylon rope attached to the back of a boat powered by an outboard motor.

Weekly sampling, beginning in May and ending in August 1976, was conducted at 2 stations in the study area. The first station was parallel to and approximately 5 m from the north shore and the second station was in the middle of the embayment. Each sample consisted of a 5-min trawl at a speed sufficient to keep the net just below the surface of the water. After each trawl, all organisms were preserved in 10 percent formalin.

During the last week of the survey, 2 shoreline seine hauls were made with a 0.8-mm mesh habitat seine at the back of the embayment in an attempt to capture fish that remained near shore after hatching.

All samples were returned to the laboratory and identified to the lowest taxon possible utilizing an unpublished key developed by Tennessee Valley Authority biologists in 1975. References by May and Gasaway (1967), Nelson (unpublished), and Siefert (1969) were helpful in identification. Total numbers and mean lengths for each identified taxon were recorded.

RESULTS AND DISCUSSION

The skipjack herring *Alosa chrysochloris*, gizzard shad *Dorosoma cepedianum*, and threadfin shad *D. petenense* were the most numerous larval Clupeidae in the townet samples. Postlarvae of that family cannot be identified readily to genus until they have developed median fins and entered the juvenile stage (May and Gasaway 1967). Those clupeids constituted 99.6 percent of the total catch while all other species made up the remaining 0.4 percent (Table 1).

The first clupeid to reach a size large enough for identification was the skipjack herring which indicates either that it spawned earlier than either species of *Dorosoma* or grew faster.

The numbers of clupeids taken in the townet increased as the water temperature

TABLE 1.—DISTRIBUTION OF PLANKTONIC LARVAL FISHES COLLECTED BY TOWNET FROM ANDERSON CREEK EMBAYMENT, KENTUCKY LAKE, KENTUCKY, MAY–AUGUST 1976

	April				May				June				July			Aug			
	9	17	25	30	9	18	26	30	5	11	20	27	7	19	31	13			
Unidentified clupeids	1	74	14	1,155	2,292	37	27	200	14	15	–	1	1	–	2	–	3,833	99.40	
Dorosoma cepedianum	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	0.03	
Dorosoma petenense	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	2	0.05	
Alosa chrysochloris	–	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–	3	0.08	
Unidentified minnows	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	0.03	
Unidentified suckers	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	0.03	
Morone sp.	2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	0.11	
Morone chrysops	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2	0.05	
Pomoxis sp.	–	–	–	1	–	–	–	2	–	–	–	–	–	–	–	–	3	0.08	
Pomoxis nigromaculatus	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	0.03	
Pomoxis annularis	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	4	0.11	
All clupeids	1	74	15	1,156	2,293	37	27	200	14	15	–	3	2	–	2	–	3,839	99.56	
All nonclupeids	3	2	2	2	–	–	1	6	–	–	–	–	–	–	–	–	16	0.44	
Totals	4	76	17	1,158	2,293	37	28	206	14	15	–	3	2	–	2	–	3,855	100.00	

increased above 19.0 C for the first time that spring on 30 April and later on 30 May 1976. A period in which the water temperatures remained below 19.0 C separated those 2 dates. Hess (1976, unpublished master's thesis, Tennessee Technological University, Cookeville, Tennessee), Rawson (1945), and Colby and Brooke (1973) also showed similar increases in the number of larval fishes with increased water temperature. A decrease in the Secchi disk readings occurred prior to the increase in the number of larvae per sample. While the increased numbers are believed to be due to temperature related spawns (Hess unpublished thesis), the increased turbidity and resultant decreased visibility tended to increase the efficiency of the townet. Noble (1970) and Scotton et al. (1973) indicated that lower light intensities helped reduce net avoidance by larval fishes with a resultant increase in catch.

So few fish were captured that little can be said concerning the temporal distribution of nonclupeid fishes. Generally, the fishes were represented by the temperate basses *Morone* sp. when the water temperature was below 17.0 C and by the crappies *Pomoxis* spp. when the water temperature was between 19.0 and 22.0 C. The differences in occurrence of those species is also believed to be due to temperature related spawns. Larval black crappies *Pomoxis nigromaculatus* were caught before white crappies *P. annularis* (Table 1) indicating that *P. nigromaculatus* probably spawned earlier than *P. annularis*.

The shoreline seine hauls resulted in the capture of juveniles of several species of fishes not captured in the townet. Those fishes, that probably spawned in Anderson Creek embayment, are: *Lepisosteus* spp., *Notemigonus crysoleucas*, *Pimephales notatus*, *Notropis atherinoides*, *Fundulus olivaceus*, *Labidesthes sicculus*, *Micropterus salmoides*, and *Lepomis* spp. The above fishes usually inhabit the littoral zone of the embayment or have demersal eggs and/or larvae that would account for their absence from the surface townet samples.

We believe that more intensive sampling at various times and depths would result in the addition of several species not encountered in the present survey.

LITERATURE CITED

COLBY, P. J., AND L. T. BROOKE. 1973. Effects of temperature on embryonic development of lake herring (*Coregonus artedi*). J. Fish. Res. Bd. Can. 30:799–810.

HUTCHINSON, G. E. 1957. A treatise on limnology. John Wiley & Sons, Inc., New York, N. Y. Vol. I. 1,015 pp.

KUEHNE, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43(4):608–614.

MARCY, B. C., JR. 1976. Planktonic fish eggs and larvae of the Connecticut Yankee Plant including entrainment. Pp. 115–139. *In* D. Merriman and L. M. Thorpe (Eds.). The Connecticut River ecological study. Amer. Fish. Soc. Monogr. No. 1, Washington, D. C. 252 pp.

MAY, E. B., AND C. R. GASAWAY. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Contrib. Okla. Fish. Res. Lab., No. 164. 33 pp.

NOBLE, R. B. 1970. Evaluation of the Miller high-speed sampler for sampling yellow perch and walleye fry. J. Fish. Res. Bd. Can. 27: 1033–1044.

RAWSON, D. S. 1945. The experimental introduction of smallmouth blackbass into lakes of the Prince Albert National Park, Saskatchewan. Trans. Amer. Fish. Soc. 73:19–31.

SCOTTON, L. N., R. E. SMITH, N. S. SMITH, K. S. PRICE, AND D. P. DE SYLVA. 1973. Pictorial guide to fish larvae of Delaware Bay with information and bibliographies useful for the study of fish larvae. Univ. Delaware, Coll. Mar. Stud., Delaware Bay Rept. Ser. 7,206 pp.

SIEFERT, R. E. 1969. Characteristics for separation of white and black crappie. Trans. Amer. Fish. Soc. 98(2):326–328.

Comparative Age, Growth, and Condition of Channel Catfish from Lake Dardanelle, Arkansas

Thomas M. Freeze[1] and Buford Tatum
Department of Fisheries and Wildlife Management, Arkansas Polytechnic College, Russellville, Arkansas 72801

Abstract

Pectoral spines were collected from 112 channel catfish *Ictalurus punctatus* from Lake Dardanelle, Arkansas, during 1973–1975 for purposes of calculating age and growth of different year classes. A length–weight relationship, determined using the equation log W = –4.3297 + 2.7216 log L, indicated that an average channel catfish from Lake Dardanelle weighs about 165 g when it reaches a harvestable size of 255 mm. Lake Dardanelle channel catfish were characterized by a large first year's growth with greater lengths similar to those from nearby states. Condition factors tended to decrease with increased age.

Introduction

In order to evaluate the ecological effects of the heated water effluent from Arkansas Power and Light Company's nuclear electric generating plant, Arkansas nuclear One, on Lake Dardanelle, it was necessary to establish baseline data on the aquatic fauna prior to the commercial operation of the plant. A ten-year study was initiated in 1973 by Arkansas Polytechnic College with funding from Arkansas Power and Light Company to accomplish that evaluation. While the populations of many organisms were sampled, this paper deals with the age, growth, and condition of Lake Dardanelle channel catfish.

Acknowledgments

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Description of Study Area

Lake Dardanelle (Fig. 1) is an impoundment of the Arkansas River in west-central Arkansas near the town of Russellville. It is a flow-through reservoir created by the U. S. Army Corps of Engineers as a part of the Arkansas River navigation project. The Arkansas River has its headwaters in the Rocky Mountains of Colorado and flows through Kansas, Oklahoma, and Arkansas before emptying into the Mississippi River approximately 150 km southwest of Memphis, Tennessee. The reservoir has a drainage area of 398,090 km^2, a conservation pool of 13,880 ha, and a shoreline length of 507 km. Completed in 1969, the reservoir is managed primarily for flood control and navigation (McGee 1972).

Materials and Methods

A total of 112 channel catfish spines was collected from Lake Dardanelle during 1973–1975 utilizing gill nets, trammel nets, and rotenone. Total lengths of the fish were recorded in inches, and weights were measured either in grams on dietetic scales or in tenths of pounds on suspension dial scales. All English units of measurements were converted to metric units before computation of data.

Left pectoral spines were disarticulated by means of the procedure outlined by Sneed (1951) and placed in numbered scale envelopes. As the spines were free of all tissue except a thin layer of skin, they received no special treatment or preservation in accordance with DeRoth (1965). The spines were sectioned using a small

[1] Present address: Department of Biological Sciences, Murray State University, Murray, Kentucky 42071.

FIG. 1. Location of Lake Dardanelle, an impoundment of the Arkansas River.

power saw on a stationary platform similar to the apparatus of Witt (1961). Unreadable sections were ground by hand on a fine carborundum stone to increase their transparency.

The distal end of the basal recess served as a reference point to ensure consistency in the location of each section (Marzolf 1955, Sneed 1951). That reference point resulted in more readable spine sections and permitted comparisons with previous studies utilizing the same method. One disadvantage in its use is that the body–spine relationship is curvilinear instead of linear (DeRoth 1965).

Approximately one-fourth of the sections were stained with alizarin red S for 3–5 sec before being rinsed with distilled water, but the procedure was discontinued as no apparent advantages in aging the sections were observed.

Spine sections were read with a binocular microscope equipped with an ocular micrometer. Measurements were made from the center of the spine lumen to the annuli and to the edge of the expanded posterior radius.

Measurements of the pectoral spine annuli were used to calculate an average rate of growth utilizing the Dahl–Lea direct proportion method (Carlander 1969). This equation may be stated as:

$$L_n = (S_n)L/S$$

where L_n = length at annulus n, S_n = spine radius at annulus n, S = total spine radius, and L = total body length.

The length–weight relationship was determined using the formula:

$$\text{Log } W = \log a + n \log L$$

where W = weight in grams, L = total length in millimeters, and a and n are empirical constants. The value of the constant n usually is above 3.0 for larger species of catfish such as the channel catfish (Carlander 1969).

The coefficients of condition (K) were computed using the formula:

$$K = 10^5 \times W/L^3$$

where W = weight in grams and L = total length in millimeters. The coefficients provided indexes for comparative analyses of plumpness or well-being of the catfish. Such calculations are based on the premise that the body form of a fish varies with the cube of increasing length provided the shape and specific gravity remain the same (Carlander 1969).

RESULTS AND DISCUSSION

The growth of Lake Dardanelle channel catfish, as determined by the Dahl–Lea equation, and the annual lengths for the 1966–1974 year classes are shown in Table 1. The average annual increments decreased gradually from 140 mm the first year to 25 mm the sixth year of life and then gradually increased to 56 mm in the ninth year. The average annual increment for the first year is approximately twice that for any of the following years. While it is normal for channel catfish to attain large percentages of their total lengths during their first 2 years of life, the unusu-

TABLE 1.—CALCULATED TOTAL LENGTHS (MM) OF 112 CHANNEL CATFISH FROM LAKE DARDANELLE, ARKANSAS, 1973–1975

Year class	Number of individuals	Year 1	2	3	4	5	6	7	8	9
1966	5	121	227	292	333	379	406	444	469	533
1967	10	143	229	283	326	374	414	453	482	
1968	13	155	230	277	330	378	427	410		
1969	28	139	207	269	322	385	374			
1970	25	144	215	276	332	348				
1971	14	145	226	289	328					
1972	12	124	195	230						
1973	4	90	163							
1974	1	102								
Average Lengths		140	213	274	328	371	396	432	477	533
Average Annual Increments		140	73	61	54	43	25	36	45	56

ally large first year's growth has resulted in greater lengths of Lake Dardanelle channel catfish than those in several nearby states for their first 4 years of life (Table 2). After the fourth year of life, the growth was approximately equal to or below that of catfish in the other lakes.

All of the studies in Table 2 were conducted on man-made reservoirs. Many of the 16 reservoirs that made up the Oklahoma study are in the same watershed as Lake Dardanelle but are closer to the headwaters of the Arkansas River. Thus, their location relative to the headwaters might result in their being less fertile than Lake Dardanelle. Each of those 16 reservoirs had been impounded more than 4 years and was labeled as old by Finnell and Jenkins (1954), and age was cited by them as the reason for the below average growth of channel catfish as compared to other Oklahoma waters.

The Lake of the Ozarks is farther north than any of the other reservoirs and that may account for the poor growth of channel catfish there. Other environmental factors undiscussed by Marzolf (1951) such as age, turbidity, and extent of reproductive success may also have acted to depress the rate of growth.

Both Norris Lake, in the eastern mountains of Tennessee, and Kentucky Lake, bordering the Jackson Purchase Area of Kentucky, were considerably older than Lake Dardanelle when they were sampled. Those conditions, plus differences in lati-

TABLE 2.—CALCULATED TOTAL LENGTHS (MM) OF CHANNEL CATFISH FROM LAKE DARDANELLE, ARKANSAS, 1973–1975 COMPARED WITH DATA FROM OTHER STUDIES

Location	Number of individuals	Calculated total lengths at end of year 1	2	3	4	5	6	7	8	9
Dardanelle Reservoir	112	140	213	274	328	371	396	432	477	533
16 Oklahoma Reservoirs (Finnell and Jenkins 1954)	3,291	91	178	249	305	363	417	472	531	577
Norris Reservoir, Tenn. (Carroll and Hall 1964)	87	99	175	272	325	373	424	457	541	
Lake of the Ozarks, Mo. (Marzolf 1951)	434	53	109	155	196	234	264	292	330	
Kentucky Lake, Ky. (Matthai 1972)	615	89	188	259	310	356	404	455		

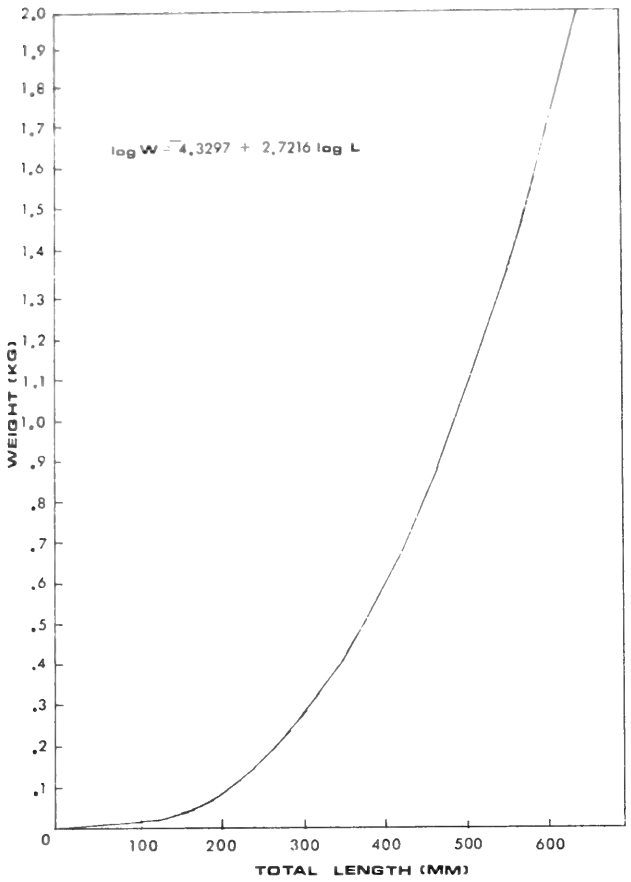

FIG. 2. Length–weight relationship of channel catfish from Lake Dardanelle.

tudes, may account for some of the variations in length attainments. While the channel catfish from Norris Lake came from a balanced population (Finnell and Jenkins 1954), the fish from Kentucky Lake were stunted as evidenced by the retardation in growth reported by Matthai (1972). Also, Lake Dardanelle being a very recently formed body of water, is experiencing what fishery biologists refer to as "peak growing conditions" due to the increased fertility of the water associated with the decay of inundated vegetation.

The length–weight relationship (Fig. 2) was calculated from 112 channel catfish ranging from 102 to 533 mm. This relationship can be expressed by the equation:

$$\text{Log } W = -4.3297 + 2.7216 \log L.$$

Channel catfish from Lake Dardanelle weighed approximately 165 g upon reaching a harvestable size of 255 mm. At 380 mm, they weighed about 500 g and at 510 mm approximately 1,080 g (Table 3).

Average coefficients of condition (K) for fish from Lake Dardanelle (Table 4) tended to decrease with an increase in age except between the fifth and sixth and between the seventh and eighth years of life. It is believed those discrepancies are due to the small sample size of older fish. The slope in the length–weight regression was less than 3.0 indicating that a decrease in condition should occur with an increase in length as observed here, since length is related to age (Carlander 1969).

In comparison, the average coefficient of condition of channel catfish from Norris Lake was erratic, while that of Kentucky Lake decreased with an increase in age until the third year of life and then increased steadily. Average coefficients of condition for channel catfish were not

TABLE 4.—AVERAGE CONDITION FACTORS (K) OF CHANNEL CATFISH IN LAKE DARDANELLE, ARKANSAS, FOR 1973–1975

Age (years)	K
1	1.17
2	1.07
3	0.99
4	0.94
5	0.85
6	0.88
7	0.83
8	0.86
9	0.82

TABLE 3.—AVERAGE TOTAL LENGTHS (MM) AND WEIGHTS (G) OF CHANNEL CATFISH FROM LAKE DARDANELLE, ARKANSAS, 1973–1975

	Age								
	1	2	3	4	5	6	7	8	9
Average length	102	163	230	328	348	374	410	482	533
Average weight	12	46	121	332	358	460	572	963	1,235
No. of individuals	1	4	12	14	25	28	13	10	5

reported by Finnell and Jenkins (1954) or Marzolf (1951).

In conclusion, the channel catfish population of Lake Dardanelle, prior to commercial operation of Arkansas Nuclear One generating plant, exhibited a large first year's growth, other length attainments comparable to studies from nearby states, and condition factors that tended to decrease with an increase in age. In most aspects, the channel catfish of Lake Dardanelle could be considered normal. However, it should be noted that the lengths of Lake Dardanelle catfish may decrease with the natural aging of the reservoir and the resultant decrease in nutrients over an extended period of time.

More recent data on the aquatic fauna of Lake Dardanelle including the channel catfish are being collected by Mr. Buford Tatum.

LITERATURE CITED

CARLANDER, K. D. 1969. Handbook of freshwater fishery biology, Vol. 1. Iowa St. Univ. Press, Ames, Iowa. 720 pp.

CARROLL, B. B., AND G. E. HALL. 1964. Growth of catfishes in Norris Reservoir, Tennessee. Tenn. Acad. Sci. 39(3):86–91.

DEROTH, G. C. 1965. Age and growth studies of channel catfish in western Lake Erie. J. Wildl. Manage. 29(2):280–286.

FINNELL, J. C., AND R. M. JENKINS. 1954. Growth of channel catfish in Oklahoma waters: 1954 revision. Okla. Fish. Res. Lab. Rept. No. 41. 37 pp.

MARZOLF, R. C. 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish. J. Wildl. Manage. 19(2):243–249.

MATTHAI, P. J. 1972. Kentucky Lake commercial catfish catch analysis. Rept. Ky. Fish Wildl. Res., Proj. 4-70-R. Res. Found., Murray St. Univ., Murray, Ky. 51 pp.

MCGEE, J. E. 1972. Your guide to the Dardanelle Reservoir area. U. S. Army Corps of Engineers Brochure, Little Rock District, Little Rock, Ark. 52 pp.

SNEED, K. E. 1951. A method for calculating the growth of cannel catfish, *Ictalurus lacustris punctatus*. Trans. Amer. Fish. Soc. 80: 174–183.

WITT, A., JR. 1961. An improved instrument to section bones for age and growth determination of fish. Prog. Fish-Cult. 23(2):94–96.

Helminth Parasites of the Spotted Sucker and Golden Redhorse from the Kentucky River[1]

David L. Combs,[2] John P. Harley, and John C. Williams
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

The following helminths were recovered from 56 spotted suckers: Acanthocephala, *Acanthocephalus* sp.; Cestoidea, *Biacetabulum banghami*, *Biacetabulum* sp., *Isoglaridacris folius*, *Monobothrium ulmeri*, and *Promonobothrium minytremi*; and 62 golden redhorse: Acanthocephala, *Acanthocephalus* sp. and *Neoechinorhynchus prolixoides*; Cestoidea, *Biacetabulum* sp., *Isoglaridacris folius*, *Monobothrium ulmeri*, and *Promonobothrium minytremi*; and Nematoda, *Camallanus oxycephalus* and *Rhabdochona* sp. from the main channel of the Kentucky River. Four of 6 species of helminths recovered from spotted suckers and 4 of 8 species recovered from golden redhorse are new host records, and 8 of 9 species recovered are new state records.

Introduction

A review of the literature indicates that only 5 published works exist on the helminth parasites of catostomid fishes from Kentucky (Aliff 1977; White and Harley 1973, 1974; White 1974; and Combs et al. 1976). All of them concern the white sucker *Catostomus commersoni* except the report by Combs et al. (1976) in which the authors reported spotted suckers *Minytrema melanops* and golden redhorse *Moxostoma erythrurum* as new host records for the monogenetic trematode *Anonchohaptor muelleri*.

As a result, it was felt that a more complete study of the parasites should be done on the spotted and redhorse suckers from the Kentucky River, and is the basis for this report.

Acknowledgments

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[2] Present address: Northeast Region Research Station, 4101 Boston Ave., Muskogee, Oklahoma 74401.

Materials and Methods

Forty-six *Minytrema melanops* and 62 *Moxostoma erythrurum* were collected from August 1973 through April 1974, from the main channel of the Kentucky River and from the mouths of 7 tributaries (Eagle Creek, Elkhorn Creek, Dix River, Red River, North, Middle, and South Forks). Most spotted suckers were collected upstream while most golden redhorse were collected downstream in the Kentucky River drainage. All fish were autopsied fresh and parasites stained by routine methods.

Results

Parasites recovered from *M. melanops* are listed in Table 1 and those from *M. erythrurum* in Table 2. Mean intensity infestation indicates the number of helminths found in each infested fish.

Nearly 1,050 individual helminths comprising 9 species were recovered from the host fishes. In *M. melanops*, 79 percent of the fish examined were infested by 1 or more helminths while in *M. erythrurum*, 54 percent were infested. Four of the 8 species of helminths recovered from *M. erythrurum* and 4 of the 6 species recovered from *M. melanops* constituted new host records. Eight of the 9 species recovered from both catostomids constitute new state records.

The following is an annotated list of hel-

TABLE 1.—MEAN INTENSITY OF INFESTATION BY HELMINTHS RECOVERED FROM 46 *MINYTREMA MELANOPS* FROM THE KENTUCKY RIVER INCLUDING NEW HOST AND STATE RECORDS

Parasite	No. fish infested	Mean intensity of infestation	Total helminths	Location	Records	
					New host	New state
Acanthocephala						
Acanthocephalus sp.	22	9	183	gut	X	
Trematoda						
Anonchohaptor sp.	12	5	56	mouth cavity	X	X
Cestoda						
Biacetabulum banghami	10	3	34	gut	X	X
Biacetabulum sp.	1	1	1	gut		X
Isoglaridacris folius	1	1	1	gut	X	X
Monobothrium ulmeri	1	2	3	gut	X	X
Promonobothrium minytremi	26	11	269	gut		X

minths recovered from *M. melanops* and *M. erythrurum* from the Kentucky River.

Acanthocephalus sp.—This acanthocephalan was designated as *Acanthocephalus* sp. because it is very closely related to *A. jacksoni*, as reported by White (1974) from the Kentucky River, and *A. dirus* (Bullock, pers. comm.). The genus *Acanthocephalus* is highly variable and causes a great deal of confusion in identification to species.

In the present study, *Acanthocephalus* sp. constituted 60 percent of all helminths found in *M. melanops* and *M. erythrurum*; it was the most abundant helminth in *M. erythrurum* and the second most abundant in *M. melanops*. This is the first report of *Acanthocephalus* sp. from either fish and thus constitutes new host records for the genus *Acanthocephalus*. The genus was first reported in Kentucky by White (1974) in *Catostomus commersoni* from the Kentucky River drainage.

Neoechinorhynchus prolixoides.—This is the first report for the species outside New Hampshire since its original description by Bullock (1963). It was found only in *M. erythrurum*, and constitutes a new host record and geographical range extension into Kentucky.

Biacetabulum banghami.—Mackiewicz (1968) first reported this caryophyllaeid cestode from *M. melanops* and *M. erythrurum* from Alabama and Oklahoma. In the present study, it was recovered only from *M. melanops*, was the fourth most abundant helminth, and constitutes a new state record.

Biacetabulum sp.—This caryophyllaeid cestode was designated as *Biacetabulum* sp. since it was very similar to specimens of *B. infrequens* Mackiewicz found (pers. comm.) in *M. erythrurum*, but our species has too few postovarian vitellaria to be *B. infrequens*. Mackiewicz (pers. comm.) believes our species might be either *B. meridianum* or a variety of that species. Further investigation is needed before species confirmation can be made.

In the present study, *Biacetabulum* sp. was recovered from both *M. melanops* and *M. erythrurum*. The occurrence of this genus in the Kentucky River thus constitutes a new state record for both fishes.

Isoglaridacris folius.—*Isoglaridacris folius* was recovered from both *M. melanops* and *M. erythrurum*. This species of caryophyllaeid cestode has been reported previously from *M. erythrurum* in Iowa by Fredrickson and Ulmer (1967). The occurrence in *M. melanops* constitutes a new host record as well as range extensions into Kentucky for both fishes.

Monobothrium ulmeri.—*Monobothrium ulmeri* was recovered from both the spotted

TABLE 2.—MEAN INTENSITY OF INFESTATION BY HELMINTHS RECOVERED FROM 62 *MOXOSTOMA ERYTHRURUM* FROM THE KENTUCKY RIVER INCLUDING NEW HOST AND STATE RECORDS

Parasite	No. fish infested	Mean intensity of infestation	Total helminths	Location	Records	
					New host	New state
Acanthocephala						
Acanthocephalus sp.	22	21	484	gut	X	
Neoechinorhynchus prolixoides	4	1	6	gut	X	X
Trematoda						
Anoncohaptor sp.	4	1	5	mouth cavity	X	X
Cestoda						
Biacetabulum sp.	3	3	9	gut		X
Isoglaridacris folius	1	1	1	gut		X
Monobothrium ulmeri	1	1	1	gut		X
Promonobothrium minytremi	12	1	16	gut	X	X
Nematoda						
Camallanus oxycephalus	8	3	24	gut		
Rhabdochona sp.	1	3	3	gut	X	X

sucker and the golden redhorse. Calentine and Mackiewicz (1966) reported the definitive hosts of *M. ulmeri* to be *Hypentelium nigricans*, *Moxostoma anisurum*, and *Moxostoma erythrurum*. The finding of this helminth in the present study constitutes a new host record for *M. melanops* and range extensions into Kentucky for both fishes.

Promonobothrium minytremi.—Mackiewicz (1968) reported the definitive host of *P. minytremi* to be *M. melanops*. In the present study, *P. minytremi* was recovered from both *M. melanops* and *M. erythrurum*. *Promonobothrium minytremi* was the second most abundant helminth in *M. erythrurum* and constitutes a new host record. In *M. melanops*, *P. minytremi* constituted the most abundant helminth with an infestation rate of 56 percent. The occurrence of *P. minytremi* in both catostomid fishes constitutes new state records.

Camallanus oxycephalus.—The nematode *C. oxycephalus* has been found in many species of fishes including several genera of catostomids (Hoffman 1967), and appears to be one of the most common helminths of freshwater fishes. In the present study, *C. oxycephalus* was recovered from *M. erythrurum* and was the third most abundant helminth in that fish as well as representing a new state record.

Rhabdochona sp.—Several species of *Rhabdochona* have been reported previously from catostomid fishes (Hoffman 1967). In the present study, *Rhabdochona* sp. was found in *M. erythrurum* and constitutes a new host and state record for the genus.

DISCUSSION

Helminth infestation rates in *M. melanops* and *M. erythrurum* were inversely proportional to the distribution of the catostomid fishes in the Kentucky River. *Moxostoma erythrurum* with a wide distribution in the river, had an infestation rate of 54 percent while *M. melanops*, with a restricted distribution, had a higher infestation rate (79%).

The helminth *Acanthocephalus* sp. exhibited the greatest density and distribution throughout the Kentucky River, while the caryophyllaeid cestode *P. minytremi*, had the second greatest density and distribution. No digenetic trematodes were recovered in this study. Their scarcity probably is attributable to the high silt load of the river that is reducing the abundance and

distribution of gastropod intermediate hosts (Leung and Williams 1975). It is of interest to note that Aliff (1977) reported relatively heavy infestations of digenetic trematodes based on extensive collections in 13 tributaries to the Kentucky River. In that study, he examined 17 golden redhorse from those tributaries and reported metacercariae of *Clinostomum* sp. in only a single fish from the Red River in Powell County.

Seasonal variation of helminths was observed in the present study with a peak intensity of infestation being reached during February and March. No difference in parasite infestation was apparent as related host sex or age, or recovery sites.

LITERATURE CITED

ALIFF, J. V. 1977. Digenetic trematodes from Kentucky fishes. Trans. Ky. Acad. Sci. 38(1–2):1–14.

BULLOCK, W. L. 1963. *Neoechinorhynchus prolixoides* n. sp. (Acanthocephala) from North American fishes. Proc. Helminthol. Soc. Wash. 30:92–96.

CALENTINE, R. L., AND J. S. MACKIEWICZ. 1966. *Monobothrium ulmeri* n. sp. (Cestoda: Caryophyllaeidae) from North American Catostomidae. Trans. Amer. Microsc. Soc. 85:516–520.

COMBS, D. L., J. C. WILLIAMS, AND J. P. HARLEY. 1976. New host records for *Anonchohaptor muelleri* (Trematoda: Monogenea) from catostomid fishes of the Kentucky River. Proc. Helminthol. Soc. Wash. 53:84.

FREDRICKSON, L. H., AND M. J. ULMER. 1967. Caryophyllaeid cestodes from two species of redhorse (*Moxostoma*). Proc. Iowa Acad. Sci. 72:444–461.

HOFFMAN, G. L. 1967. Parasites of North American freshwater fishes. Univ. Cal. Press, Los Angeles, Cal. 486 pp.

LEUNG, S. S., AND J. C. WILLIAMS. 1975. Commercial Fishery Investigations of the Kentucky River. Water and Silt Analysis. East. Ky. Univ. Press, Richmond, Ky. 77 pp.

MACKIEWICZ, J. S. 1968. Two new caryophyllaeid cestodes from the spotted sucker, *Minytrema melanops* (Raf.) (Catostomidae). J. Parasitol. 54:808–813.

WHITE, G. E. 1974. Parasites of the common white sucker (*Catostomus commersoni*) from the Kentucky River Drainage. Trans. Amer. Microsc. Soc. 93:280–282.

———, AND J. P. HARLEY. 1973. Helminth parasites of the white sucker, *Catostomus commersoni*, from Lake Wilgreen in Kentucky. Trans. Ky. Acad. Sci. 34(3–4):53–54.

———, AND ———. 1974. Helminth parasites of the white sucker (Pisces: Catostomidae) in the Kentucky River Drainage. Trans. Ky. Acad. Sci. 35(1–2):24–26.

Parasites of Channel Catfish from the Kentucky River, with a Comparative Note on the Ohio River[1]

Robert W. Edwards,[2] John P. Harley, and John C. Williams
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

One hundred sixty-one channel catfish were collected from the Kentucky River drainage from April 1975 through June 1976 and examined for parasites.

The parasites recovered were: Trematoda: *Acetodextra amiuri*; Cestoda: *Corallobothrium* sp., *C. fimbriatum*, *C. giganteum*; Nematoda: *Contracaecum* sp.; and Crustacea: *Ergasilus arthrosis*. Seasonal variation was observed in *A. amiuri*, *C. fimbratum*, *C. giganteum*, and *E. arthrosis*. *Acetodextra amiuri*, *Contracaecum* sp., *C. giganteum*, and *E. arthrosis* are new state records.

Introduction

The channel catfish *Ictalurus punctatus* is a moderately abundant and very desirable food fish of the Kentucky River drainage system (Williams 1974). However, the parasitic organisms of *I. punctatus* in the Kentucky River drainage have been neglected with the exception of Aliff's (1977) work on the digenetic trematodes and Bauer and Harley's (1973) work on cestodes. Thus, the present study was done to further the information on the parasites of *I. punctatus* in the Kentucky River by: (a) identification of parasites, (b) determining geographical distribution, and (c) noting any seasonal variation in helminth species.

Materials and Methods

One hundred sixty-one channel catfish were collected from the Kentucky River drainage from April 1975 through June 1976.

In the main channel, fish were captured by setting 1.5- and 2-inch (3.75–5.0-cm) gill nets and lifting them 24 hours later. Fish captured in locks on the river and from coves in Herrington Lake, a tributary to the Kentucky River, were killed with Pronox-Fish (5% emulsifiable rotenone) at a concentration of 1 ppm at the collection sites. Potassium permanganate was used to oxidize any Pronox-Fish that escaped through the lower lock gate and the area of the blocknet when treating an open cove on Herrington Lake by placing it in porous nylon bags and towing behind the boat throughout the study area after the treatment was completed.

Specimens to be examined were transported to the laboratory on ice and all other fish were buried. In the laboratory, fish usually were autopsied within 72 hours; fish that could not be examined within 72 hours were frozen for later examination. Fish were autopsied by routine procedures, and individual organs were removed and placed in separate Petri dishes with Ringer's solution (0.7%).

Gills and individual organ systems were examined by teasing the tissues apart; stomach and intestine were dissected with fine scissors and the "strip technique" utilized. All helminths and parasitic copepods recovered were placed in Ringer's solution (0.7%) for gross macroscopic examination.

Helminths and parasitic copepods were fixed in hot standard alcohol–formalin–acetic acid solution (AFA). Specimens not to be stained were placed in large screwtop vials filled with AFA.

Specimens were stained in Harris hematoxylin, cleared in xylene, and mounted in

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[2] Present address: Department of Zoology, University of Arkansas, Fayetteville, Arkansas 72701.

TABLE 1.—MEAN INTENSITY OF INFESTATION BY PARASITES RECOVERED FROM 161 *ICTALURUS PUNCTATUS* FROM THE KENTUCKY RIVER INCLUDING NEW STATE RECORDS

Parasite	No. fish infested	Mean intensity of infestation	Total parasites	Location	New state record
TREMATODA					
Acetodextra amiuri	2	4	8	ovary	X
CESTODA					
Corallobothrium sp.[1]	18	2	29	intestine	
Corallobothrium giganteum	11	3	28	intestine	X
Corallobothrium fimbriatum	14	3	38	intestine	
NEMATODA					
Contracaecum sp.	10	1	14	mesenteries	X
CRUSTACEA					
Ergasilus arthrosis[2]	108	24	2,590	gills	X

[1] Immature.
[2] Females only.

Permount. Nematodes were fixed by dropping them in hot 70 percent alcohol.

Confirmation of helminth species was made by Dr. David A. Becker, Department of Zoology, University of Arkansas, Fayetteville, Arkansas, and Donald Cloutman, Duke Power Company, Huntersville, North Carolina.

Mean intensity of infestation indicates the number of parasites in each infested fish.

RESULTS AND DISCUSSION

During the sampling period, approximately 2,700 individual parasitic organisms representing 6 species were recovered. Seventy-one percent of the fish examined were infested by 1 or more parasitic organisms. Four of the 6 species of parasites recovered constituted new state records. The following is an annotated list of parasites recovered from *I. punctatus* (Table 1).

Acetodextra amiuri.—A total of 8 individuals was found in the gravid ovaries of only 2 (1%) of the fish examined (Table 1). The low number of individuals as well as the low percentage of infestation probably was due to the loss of most of the adults during spawning. The helminth exhibits seasonal variation related directly to the spawning time of the fish, and very few or no helminths were present after the fish spawned. This was consistent with the results of the present study because the majority of collections were made either too early or too late to coincide with spawning in *I. punctatus.*

In this study, immature adults were found within the ova and mature adults were free in the ovaries. According to Warner and Hubert (1975) there is no question that *A. amiuri* destroys ovarian tissue and ova in *I. punctatus.*

A. amiuri has been reported from the ovaries, gas bladder, urinary bladder, and the liver of ictalurid fishes (Warner and Hubert 1975). Aliff (1977) reported it from the urinary bladder of *I. melas* recovered from the Kentucky River. The present report represents a new state record for *A. amiuri* in *I. punctatus.*

Corallobothrium sp.—An immature form of the cestode genus *Corallobothrium* was recovered from 18 (11%) of the fish examined, with a total of 29 individual helminths collected (Table 1). The cestode was in what seemed to be an immature form; however, it was capable of inhabiting the definitive host year round.

Corallobothrium giganteum.—This proteocephaline cestode was recovered from 11 (7%) of the fish examined with a mean intensity of infestation of 3 (Table 1). Twenty-eight individual cestodes were re-

covered from *I. punctatus* during the summer. This helminth was very similar to the *C. fimbriatum* recovered and was distinguished by the smooth-surfaced scolex versus the large fimbriate scolex with marginal lappets of *C. fimbriatum.*

The study showed that *C. giganteum* demonstrated seasonal variation very similar to that of *C. fimbriatum* and was recovered only in the summer as fully segmented adults.

Corallobothrium fimbriatum.—Bauer and Harley (1973) reported the caryophyllaeid cestode *Corallobothrium fimbriatum* from *I. punctatus* in Kentucky as being fully developed, segmented adults. The *C. fimbriatum* of the present study were consistent with those findings and contrary to the report of Van Cleave and Mueller (1934) in which they reported that *C. fimbriatum* (in *I. punctatus*) were small and unsegmented, suggesting that the fish was an unsuitable host.

A total of 38 individual helminths was collected from 14 *I. punctatus* with a mean intensity of infestation of 3 (Table 1). Seasonal variation was shown, however, since the cestode was recovered as a segmented adult only during the summer and in immature forms in the spring and fall.

Contracaecum sp.—The only nematode recovered from *I. punctatus* during the present study was *Contracaecum* sp. Fourteen individual nematodes were recovered with a mean intensity of infestation of 1, with 10 (6%) of the fish infested (Table 1).

The nematode had 3 large lips, with well-developed interlabia and intestinal caecum present. Also, there were cuticular papillae on the surface of the external cuticle.

This nematode was found only in fish collected in Kathy's Cove on Herrington Lake, an impoundment of the Dix River, and constituted a new state record. It was also reported by White and Harley (1974) in the white sucker *Catostomus commersoni.*

Seasonal variation could not be confirmed due to the scarcity of the nematodes in the study.

Ergasilus arthrosis.—The report of the parasitic copepod *Ergasilus arthrosis* in this study was the first record of the species in Kentucky; however, it appears to be common on the gills of ictalurids in North America (Roberts 1970). Because of the synonymy with *E. versicolor*, many investigators have mistaken *E. arthrosis* for *E. versicolor*, since the main distinguishing characteristic between them is that the first endopod in *E. arthrosis* has 3 segments and that in *E. versicolor* has 2 segments (Roberts 1970).

In the present study, *E. arthrosis* was the only copepod species infesting *I. punctatus.* One hundred eight (67%) of the fish examined were infested, and a total of 2,590 copepods were recovered with a mean intensity of infestation being 24 (Table 1).

All *E. arthrosis* recovered were females; males occur only in the free-living form and die after copulation (Hoffman 1967).

E. arthrosis showed seasonal variation during the study, with the highest infestation during summer and little or none during fall and winter.

In cases of high infestation, the parasite could have deleterious effects on the fish, especially young individuals, since the parasites attach to and feed from the individual gill filaments. In cases of high infestation, the result may be stunting of growth, and in extremely high infestations (due to tissue damage and toxic wastes produced by the parasite) the results may be lethal (Hoffman 1967). During spring and summer, all fish examined were parasitized; however, the infestations were not extremely heavy. The mean intensity of infestation ranged from 9 to 49 in spring and summer, with higher values being recorded from Herrington Lake. In this study, none of the fish examined showed any signs of deleterious effects from *E. arthrosis.*

The collection of *I. punctatus* and subsequent parasitological survey of the specimens taken from the Ohio River for comparison with those from the Kentucky River

were similar in terms of the parasitic organisms recovered during similar seasons.

Parasitic infestation in the present study showed no pathological effects on *I. punctatus*, and the fish were in relatively good condition with no anomalies observed that could be attributed to parasitic infestations.

LITERATURE CITED

ALIFF, J. V. 1977. Digenetic trematodes from Kentucky fishes. Trans. Ky. Acad. Sci. 38(1–2):1–14.

BAUER, B. H., AND J. P. HARLEY. 1973. Intestinal parasites from two species of catfishes (Ictaluridae) from Wilgreen Lake in Kentucky. Trans. Ky. Acad. Sci. 34(3–4):55–56.

HOFFMAN, G. L. 1967. Parasites of North American Freshwater Fishes. Univ. Cal. Press, Los Angeles, Cal. 486 pp.

ROBERTS, L. S. 1970. *Ergasilus* (Copepoda: Cyclopoida): revision and key to species in North America. Trans. Amer. Microsc. Soc. 89(1):134–161.

VAN CLEAVE, H. J., AND J. F. MUELLER. 1934. Parasites of Oneida Lake fishes. Part III. A biological and ecological survey of worm parasites. Roosevelt Wildl. Ann. 3(3–4):161–334.

WARNER, M. C., AND W. A. HUBERT. 1975. Notes on the occurrence of *Acetodextra amiuri* (Stafford) (Trematoda: Heterophidae) in channel catfish from the Tennessee River. J. Wildl. Dis. 11:37.

WHITE, G., AND J. P. HARLEY. 1974. Helminth parasites of the white sucker (Pisces: Catostomidae) in the Kentucky River Drainage. Trans. Ky. Acad. Sci. 35(1–2):24–26.

WILLIAMS, J. C. 1974. Commercial fishery investigations of the Kentucky River. Final Report 2-186-R. NOAA, Natl. Mar. Fish. Serv., and Ky. Dept. Fish Wildl. Res., Frankfort, Ky. 184 pp.

Parasites of the White Crappie from Lake Wilgreen, Kentucky[1]

John P. Harley
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

A survey of 150 white crappies from Lake Wilgreen, Kentucky, yielded 8 species of parasites. New host records are reported for *Contracaecum brachyurum* and *Ergasilus arthrosis*. New state records in the white crappie are reported for *Crepidostomum cornutum*, *Postodiplostomum minimum*, *Proteocephalus ambloplitis*, *Camallanus oxycephalus*, *Contracaecum brachyurum*, *C. spiculigerum*, *Pomphorhynchus bulbocolli*, and *Ergasilus caeruleus*.

Introduction

To the author's knowledge, the only published work on parasites of the white crappie *Pomoxis annularis* in Kentucky is that of Aliff (1977). He reported a 7 percent rate of infestation with only *Proterometra* sp. being recovered. The present study was undertaken to contribute further information on parasites of the white crappie in Kentucky.

Materials and Methods

One hundred fifty white crappies were collected between June and October 1976 from Lake Wilgreen, Madison County, Kentucky. The fish were autopsied and the parasites fixed, stained, and identified according to previously reported procedures (Harley and Keefe 1970, White and Harley 1974).

Results

During the sampling period, approximately 7,300 individual parasitic organisms representing 8 species were recovered from the 150 white crappies autopsied. There was an average of nearly 50 parasites per fish. The following is an annotated list of parasites recovered from *P. annularis* (Table 1).

Pomphorhynchus bulbocolli.—A total of 485 individuals was found in the intestine of 100 (66%) of the fish examined. The second intermediate host for this parasite is small fish (Cyprinidae). Thus, since minnows constitute a major portion of the white crappie's diet, this could possibly explain the high infestation rate.

According to Ribelin and Migaki (1975), the attachment sites of the very damaging proboscis in the intestine are the seat of prominent lesions and malabsorption syndromes. Since the mean intensity of infestation by this acanthocephalan was high (38/fish), this could possibly be one of the reasons for the overall small size and growth rate of the white crappie in Lake Wilgreen.

Crepidostomum cornutum.—Only 63 individuals were recovered from the intestines of 18 white crappies for a mean intensity of infestation of 5. The low numbers recovered are indications of the fact that one of the intermediate hosts for this trematode is sphaeriid clams of which there are few in Lake Wilgreen.

Posthodiplostomum minimum.—Although large numbers (4,500) of metacercariae were recovered, the mean intensity of infestation (104) and the number of fish infested (43) were light when compared to data from *Lepomis* sp. (Harley and Keefe 1970) in Lake Wilgreen. Overall, crappies do not seem to be as suitable a host for the metacercariae as other Centrarchidae (Hoffman 1967) and that may explain the low levels of infestation. Nevertheless, the plentiful quantity of *Physa integra* and the continued presence of herons probably will

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TABLE 1.—MEAN INTENSITY OF INFESTATION BY VARIOUS PARASITES OF 150 WHITE CRAPPIES FROM LAKE WILGREEN, KENTUCKY, INCLUDING NEW HOST AND STATE RECORDS

Parasite	No. fish infested	Mean intensity of infestation	Total parasites	Location in fish	New host record	New state record
ACANTHOCEPHALA						
Pomphorhynchus bulbocolli	100	38	485	intestine		X
TREMATODA						
Crepidostomum cornutum	18	5	63	intestine		X
Posthodiplostomum minimum[1]	43	104	4,500	liver, heart, kidney		X
CESTOIDEA						
Proteocephalus ambloplitis[2]	25	6	91	viscera		X
NEMATODA						
Camallanus oxycephalus	121	12	1,001	anus		X
Contracaecum spiculigerum[3]	3	4	8	stomach, intestine		X
Contracaecum brachyurum[3]	9	5	37	stomach, intestine	X	X
CRUSTACEA						
Ergasilus arthrosis	34	33	1,129	gills	X	X

[1] Encysted larvae. [2] Plerocercoids. [3] Larvae.

maintain this parasite in white crappies in this lake.

Proteocephalus ambloplitis.—Only 91 plerocercoids of this proteocephalid were recovered from 25 crappies with a mean intensity of infestation of 6. These plerocercoids have been reported from the viscera of many species of small fishes (Hoffman 1967) which act as "carriers." Thus, in Lake Wilgreen, the white crappie is a carrier for the plerocercoid of the bass tapeworm and does not harbor the adult worm.

Camallanus oxycephalus.—This nematode was the most prevalent parasite recovered. Eighty percent of the autopsied fish harbored this worm with a mean intensity of infestation of 12. By comparison, Harley and Keefe (1970) found a mean intensity of infestation in *Lepomis* sp. of 4 with only 10 percent of the fish being infested. Thus, in Lake Wilgreen, *Pomoxis annularis* seems to harbor more *C. oxycephalus* than *Lepomis* sp. The reason for this difference cannot be explained based on available data.

Contracaecum spiculigerum.—This nematode was the least prevalent of all parasites recovered. Only 8 were recovered from 3 crappies for a mean intensity of infestation of 4 with 2 percent of the autopsied fish being infested. Since the larvae have been reported from many species of fishes (Hoffman 1967), there probably is no fish host specificity. The finding of *C. spiculigerum* can be accounted for by the occasional appearance of gulls (Laridae) on the lake. Gulls normally harbor the adults.

Contracaecum brachyurum.—Only 37 larvae were recovered from 9 crappies for a mean intensity of infestation of 5 with 6 percent of the autopsied fish being infested. Like for *C. spiculigerum*, gulls normally harbor the adults, the larval forms infesting the fish that eat them.

Ergasilus arthrosis.—This parasitic copepod was very prevalent on the gills of the autopsied white crappies. Twenty-three percent of the fish surveyed harbored this parasite with a mean intensity of infestation of 33. This was slightly higher than the mean intensity (24) reported by Edwards et al. (1977) for the channel catfish from the Kentucky River. The difference can be accounted for in that *E. arthrosis*

shows seasonal variation with the highest infestation occurring during summer. In this survey, all crappies were collected during summer, while in the survey by Edwards et al. (1977), the channel catfish were collected over a period of 14 months, including winter, which lowered their average rate of infestation.

DISCUSSION

Contracaecum brachyurum and *Ergasilus arthrosis* from the white crappie are new host records for the United States. Those 2 parasites, along with all others recovered, constitute new state records for *Pomoxis annularis* as a host.

With the exception of *Crepidostomum cornutum* and *Ergasilus arthrosis*, all the other parasites have been reported previously from other sunfishes (*Lepomis*) from Lake Wilgreen (Harley and Keefe 1970).

The finding of the parasitic copepod, *E. arthrosis*, is the second report for Kentucky. Edwards et al. (1977) reported it from channel catfish in the Kentucky and Ohio rivers and explained why it has been mistaken for *E. versicolor*.

When compared to other studies on the white crappie (Dechtiar 1972, Becker and Houghton 1969, Arnold et al. 1968, Allison and McGraw 1967) in different parts of the country, the present study has shown a wider diversity and number of parasites recovered. A possible explanation for this is the large number and variety of invertebrate hosts present in Lake Wilgreen (Sugantharaj 1972, unpublished master's thesis, Eastern Kentucky University, Richmond, Kentucky) that the white crappie feeds upon. Also, the lake is highly polluted (Otero and Leung 1972) and this may have something to do with the high diversity of micro- and macroorganisms that serve as food for the white crappie. Apparently, the high rate of parasitic infestation is not unusual for fish in central Kentucky as indicated by other studies (Aliff 1977, Combs et al. 1977, Edwards et al. 1977, White and Harley 1974).

LITERATURE CITED

ALIFF, J. V. 1977. Digenetic trematodes from Kentucky fishes. Trans. Ky. Acad. Sci. 38(1–2):1–14.

ALLISON, T. C., AND J. L. MCGRAW. 1967. The helminth parasites of Centrarchidae from the Navasota River System of Texas. Texas J. Sci. 19:326–327.

ARNOLD, J. G., H. E. SCHAFER, AND R. L. VULLIET. 1968. The parasites of the fresh water fishes of Louisiana. II. Check list of parasites. Proc. Ann. Conf. Southeast. Ass. Game Fish Comm. 21:531–543.

BECKER, D. A., AND W. C. HOUGHTON. 1969. A survey of the helminth parasites of selected game fishes of Lake Fort Smith, Arkansas. Proc. Ark. Acad. Sci. 23:110–117.

COMBS, D. L., J. P. HARLEY, AND J. C. WILLIAMS. 1977. Helminth parasites of the spotted and golden redhorse suckers from the Kentucky River. Trans. Ky. Acad. Sci. 38(3–4):128–131.

DECHTIAR, A. O. 1972. New parasite records for Lake Erie Fish. Great Lakes Fish. Comm. Tech. Rept. No. 17:1–11.

EDWARDS, R. W., J. P. HARLEY, AND J. C. WILLIAMS. 1977. Parasite fauna of channel catfish from the Kentucky River with a comparative note on the Ohio River. Trans. Ky. Acad. Sci. 38(3–4):132–135.

HARLEY, J. P., AND T. L. KEEFE. 1970. Helminth parasites of four species of sunfishes (Centrarchidae) from Lake Wilgreen in Kentucky. Trans. Ky. Acad. Sci. 32(3–4):71–74.

HOFFMAN, G. L. 1967. Parasites of North American Freshwater Fishes. Univ. Cal. Press, Los Angeles, Cal. 486 pp.

OTERO, R. B., AND S. LEUNG. 1972. Some observations on bacterial populations in Wilgreen Lake, Madison County, Kentucky. Trans. Ky. Acad. Sci. 33(1–2):16–26.

RIBELIN, W. E., AND G. MIGAKI. 1975. The pathology of fishes. Univ. Wis. Press, Madison, Wis. 1,004 pp.

WHITE, G., AND J. P. HARLEY. 1974. Helminth parasites of the white sucker (Pisces: Catostomidae) in the Kentucky River drainage. Trans. Ky. Acad. Sci. 35(1–2):24–26.

Gas Chromatographic Analysis of Bromoquinolines

Jerry L. Butler and Marshall Gordon
Department of Chemistry, Murray State University, Murray, Kentucky 42071

Abstract

Excellent separations of isomeric bromoquinolines have been obtained using a packed column containing QF-1. The method of analysis was used to assay various products obtained from bromination of quinoline. Observed retention time ranged from 373 sec for quinoline to 1,643 sec for 8-bromoquinoline with respective indexes of 1,596 and 2,018.

Introduction

The literature reveals little information pertaining to the separation of quinoline derivatives by gas chromatography. Gas chromatography has been used to follow the reaction kinetics of styrylquinoline formation (Lynch and Gordon 1972). The first reported attempt to separate isometric halogenated quinolines was by Goodley and Gordon (1972), who developed a method for the rapid separation and quantitative analysis of selected chlorinated quinolines by gas chromatography.

For separation of the bromoquinolines, the McReynolds (1970) constants indicate that QF-1 would be a good choice and that OV-225 should also be considered. The ability of QF-1 to retard the nitromethane type molecule and the electron donor type molecules seems to involve an interaction between the unshared pair of electrons (quinoline) with the trifluoropropyl group of the liquid phase. Such being the case, retention time should be a function of the electron density at the nitrogen atom. However, it appears from retention data that separation is achieved by a dipole–dipole interaction between the quinoline ring structure and trifluoropropyl group of the liquid phase.

Acknowledgment

Partial support of this work by the Murray State University Committee on Institutional Studies and Research is gratefully acknowledged.

Materials and Methods

The liquid phase used was a silicone QF-1 coated onto Chromosorb G, AW, DMCS, 60/70-mesh support and packed into a 10 ft × 0.093 in (3.04 m × 0.236 cm), 1/8 in od (0.32 cm) aluminum tube. There was no pretreatment of the support; it was used as received (Johns-Manville Corp.). Of the 5 different liquid loadings tested (range 5–20%), the optimum loading was 10 percent. Other liquid phases, SE-30, OV-225, and Apiezon L, and support materials Chromosorb W, regular; Chromosorb W, DMCS; Chromosorb G, DMCS; and Chromosorb T were found to be ineffective for the separation of the bromoquinolines. Helium was used as a carrier gas for all analyses. The column temperature was 163 C; the injector port temperature was 210 C; the detector temperature was 225 C. Sample size was 0.06 μl; the carrier gas flow rate was 14.4 ml/min. An effluent splitter located at the column–flame base junction effectively allowed 49 percent (6.6 ml/min) of the effluent to bypass the detector. The remaining 51 percent effluent (7.8 ml/min) entered the hydrogen flame. The recorder used was a Honeywell 1.0 mv full-scale, Model 1630, connected to an Infotronics Digital Integrator, Model CRS-104. The gas chromatograph was a dual channel Varian Aerograph, Model 1520, equipped with flame–ionization detectors.

Results and Discussion

The retention index values, according to Kovats (1967) and Rohrschneider (1966,

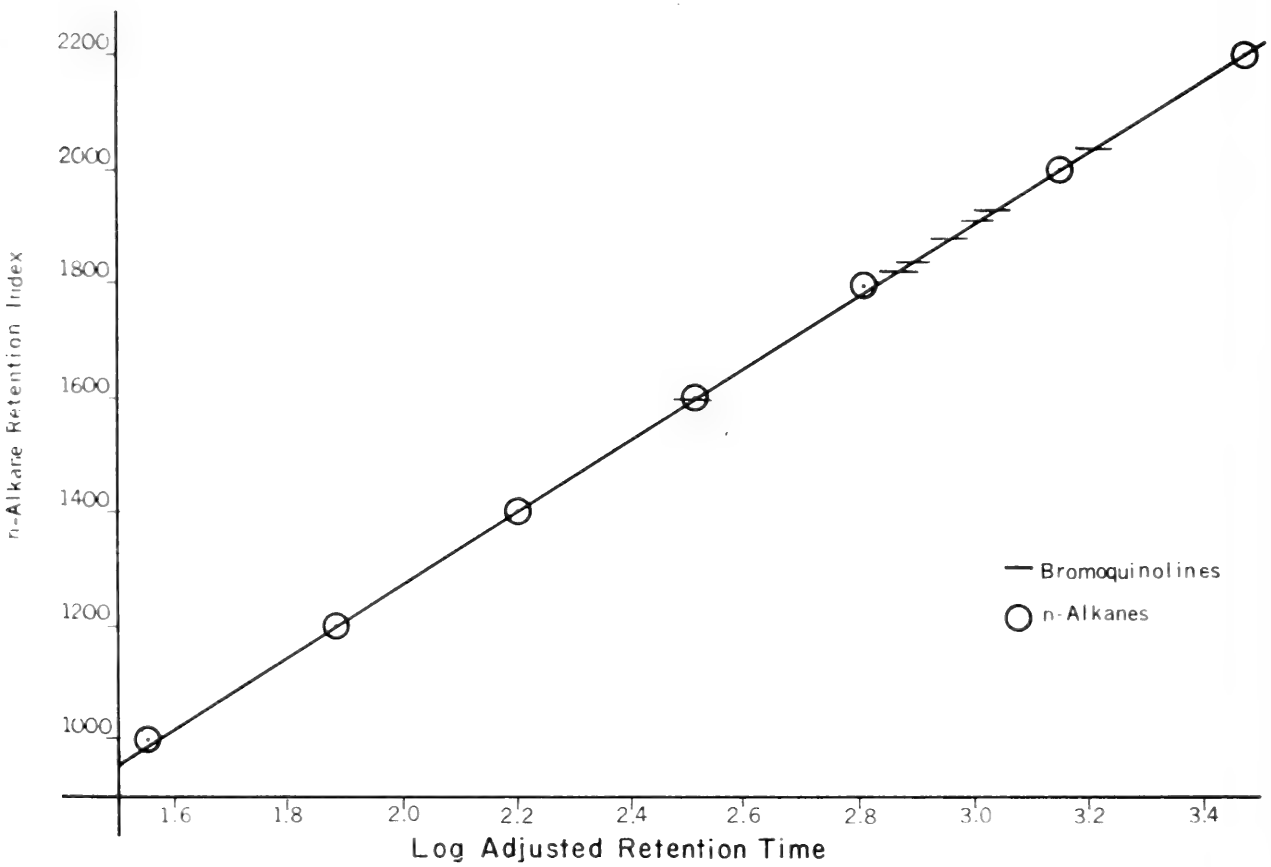

FIG. 1. Plot of log adjusted retention time for the bromoquinoline versus the n-alkane retention index.

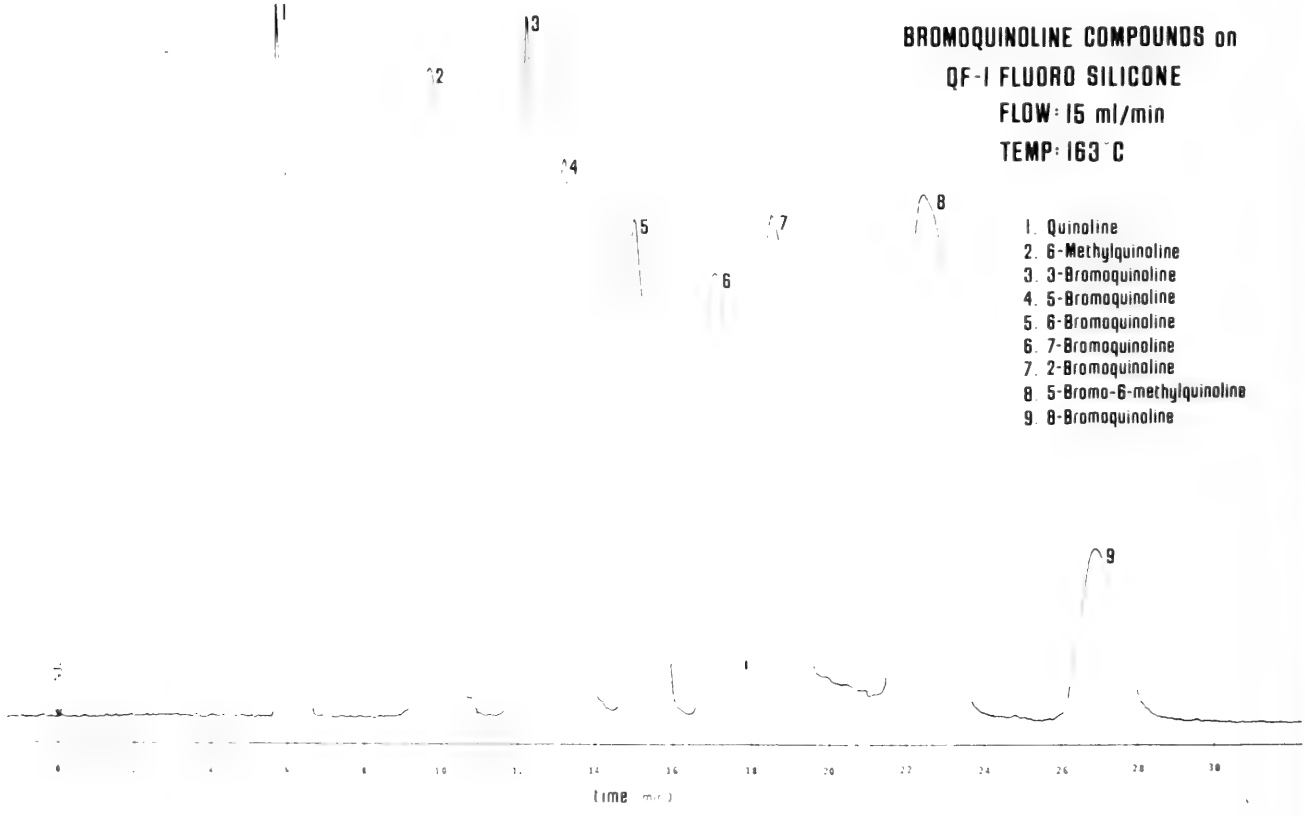

FIG. 2. Typical chromatogram of a standard mixture of the bromoquinoline.

TABLE 1.—RETENTION DATA FOR BROMINATED QUINOLINE ISOMERS ON QF-1 AT 163 C AND 15 ML/MIN FLOW RATE

Compound	Observed retention time (sec)	Adjusted retention time (sec)	Log adjusted retention time	Retention index
methane	37	0	0.0000	100
heptane	48	11	1.0414	700
decane	73	36	1.5563	1,000
dodecane	114	77	1.8865	1,200
tetradecane	199	162	2.2095	1,400
hexadecane	378	341	2.5328	1,600
octadecane	736	699	2.8445	1,800
eicosane	1,469	1,432	3.1559	2,000
decosane	4,982	4,945	3.6942	2,200
quinoline	373	336	2.5263	1,596[1]
3-bromoquinoline	762	725	2.8603	1,810[1]
5-bromoquinoline	821	784	2.8943	1,832[1]
6-bromoquinoline	929	892	2.9504	1,868[1]
7-bromoquinoline	1,060	1,023	3.0094	1,906[1]
2-bromoquinoline	1,151	1,114	3.0468	1,930[1]
8-bromoquinoline	1,643	1,606	3.2055	2,018[1]

[1] These values were obtained from the equation

$$I = 200 \frac{\log t'_{Ri} - \log t'_{Rz}}{\log t'_{R(z+2)} - \log t'_{Rz}} + 100\ Z.$$

1967), were found by injecting the normal alkanes into the chromatograph using the same conditions for the bromoquinoline analysis and plotting the log adjusted retention time versus the n-alkane number multiplied by 100 (the n-alkane index) (Fig. 1). Methane was used to obtain a relative reference for the adjusted retention time using the hydrogen flame detector. The conditions for the quinoline isomer analysis were duplicated, using a thermal conductivity detector to establish the fact that air and methane had the same retention time on the QF-1 column. The index values and accompanying data for the QF-1 column at 163 C are shown in Table 1.

Six standard mixtures were made using a wide difference in composition of the quinoline isomers. These mixtures were weighed out on a Mettler balance to the nearest 0.01 mg. Four to 6 injections of each of the 6 standard mixtures were made into the chromatograph, and an average response value for each component was calculated from the observed area of each component. The response factors were calculated on the basis of mole percent composition and related to quinoline as arbitrarily having a response factor of 1.00 (Dietz 1967). The values are shown together with the composition of one of the standards and results from a typical analysis in Table 2.

TABLE 2.—BROMINATED QUINOLINE ANALYSIS AND RELATIVE RESPONSE VALUES ON QF-1 AT 163 C

Compound	Standard (mole percent)	Average analysis (mole percent)	Error	Average response factor
quinoline	22.21	22.37	+0.16	1.00
2-bromoquinoline	11.56	11.45	−0.11	1.10
3-bromoquinoline	13.94	13.85	−0.09	0.99
5-bromoquinoline	11.39	11.45	+0.06	1.04
6-bromoquinoline	12.87	12.72	−0.15	0.99
7-bromoquinoline	14.92	14.90	−0.02	1.05
8-bromoquinoline	13.11	13.16	+0.05	0.98
Total	100.00	100.00		

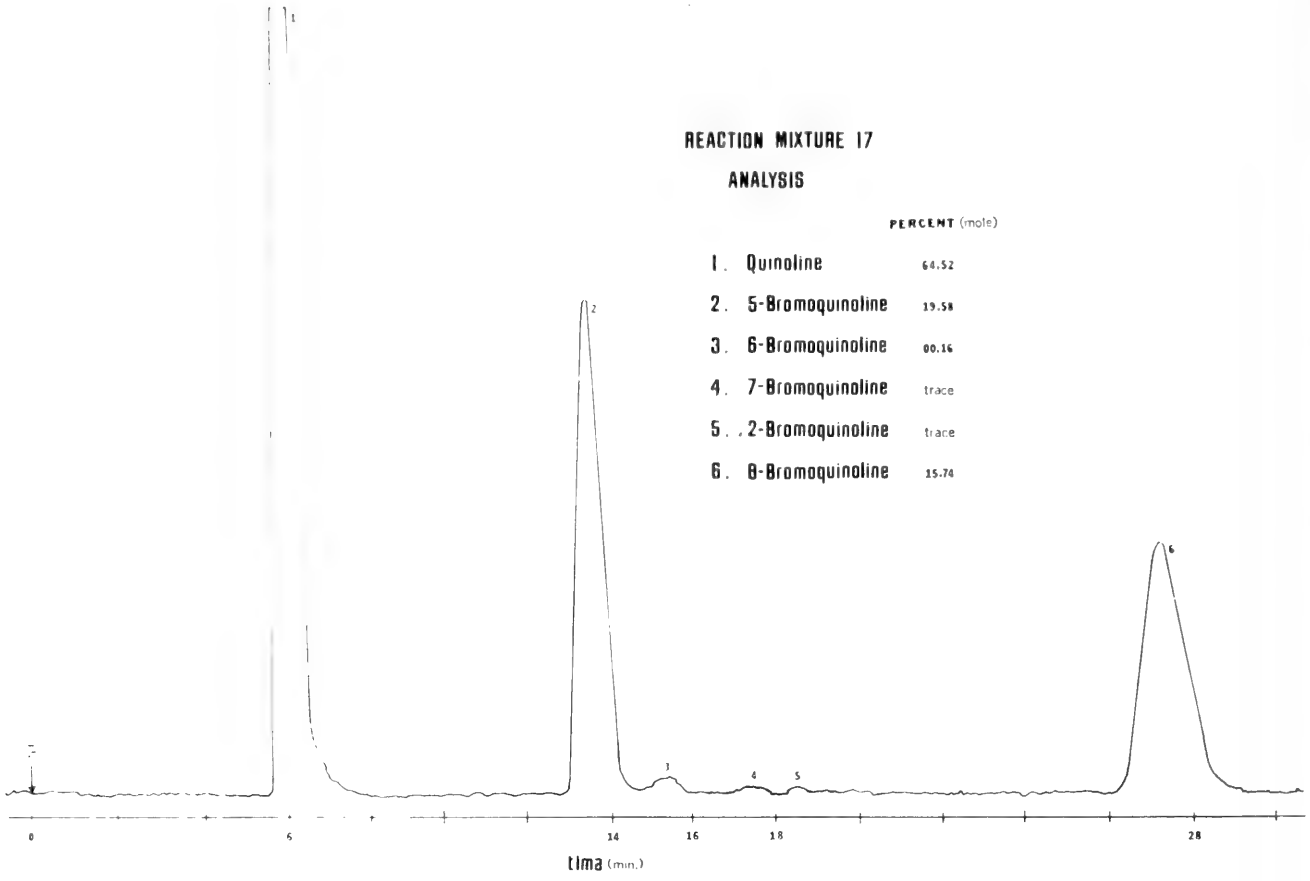

FIG. 3. Typical chromatogram of a bromination reaction mixture.

A discussion of the preparation of bromoquinoline isomers together with details of various bromination reactions conducted is reported elsewhere (Butler and Gordon 1975).

The brominated quinoline reaction mixtures were analyzed in the same way as the standard mixtures. The mole percent of each isomer present was calculated from the product of the area obtained and the response factor for that isomer. In some analyses, there was a rise in the baseline of the chromatograph recording, but the area was not sufficient for the electronic integrator to respond. For those instances, the isomers present, in obviously small amounts, were indicated as "trace." Figs. 2 and 3 illustrate chromatograms of a standard mixture and a reaction mixture, respectively.

LITERATURE CITED

BUTLER, J. L., AND M. GORDON. 1975. A reinvestigation of known bromination reactions of quinoline. J. Heterocyclic Chem. 12:1015–1020.

DIETZ, W. A. 1967. Response factors for gas chromatographic analyses. J. Gas Chromatogr. 5:68.

GOODLEY, P. C., AND M. GORDON. 1972. Gas chromatographic analysis of halogenated quinoline compounds. J. Chromatogr. Sci. 10:532–534.

KOVATS, E. 1967. Gas chromatographic characterization of organic substances in the retention index system. Pp. 229. *In* J. C. Giddings and R. A. Keller (Eds.). Advances in Chromatography, Vol. 1. Marcel Dekker Co., New York, N.Y. 392 pp.

LYNCH, S. M., AND M. GORDON. 1972. Kinetics of styrylquinoline formation. J. Heterocyclic Chem. 9:789–799.

MCREYNOLDS, W. O. 1970. Characterization of some liquid phases. J. Chromatogr. Sci. 8: 685–691.

ROHRSCHNEIDER, L. 1966. A method for the characterization of gas chromatographic stationary liquids. J. Chromatogr. 22:6.

————. 1967. The polarity of stationary liquid phases in gas chromatography. Pp. 333. *In* J. C. Giddings and R. A. Keller (Eds.). Advances in Chromatography, Vol. 4. Marcel Dekker Co., New York, N.Y. 380 pp.

Distribution of the Barking Treefrog in Kentucky[1]

Burt L. Monroe, Jr. and Raymond W. Giannini
Department of Biology, University of Louisville, Louisville, Kentucky 40208

Abstract

Discovery of a second population of *Hyla gratiosa* in Caldwell County, Kentucky, isolated from the only other known population in the state (Todd County and adjacent Montgomery County in Tennessee), suggests that the disjunct nature of the northern populations is a result of range contraction and the natural occurrence of relict populations rather than from artificial introductions by man.

North of the central Gulf states, from northern Alabama and northwestern Georgia through central Tennessee, the barking treefrog *Hyla gratiosa* is represented by disjunct, apparently relict populations. At the extreme north-central limit of the range in north-central Tennessee and south-central Kentucky, the species has been heretofore known from a single population in Montgomery County, Tennessee (Scott and Harker 1968), and adjacent Todd County, Kentucky (Monroe and Taylor 1972). The discovery of an additional isolated population about 60 km northwest of the foregoing extends the range of the species toward southwestern Kentucky and further illustrates the peculiar disjunct nature of its distribution.

On 3 July 1976, Giannini obtained a single specimen about 12 km south of Princeton, Caldwell County, Kentucky. It was taken about 50 m from the nearest water on a warm, drizzly night; no frogs were heard calling at that time. The specimen is presently in the Herpetological Collections of the Department of Biology, University of Louisville (#UL 6779).

Following considerable rainfall, Giannini located a breeding area on 5 July about 75 m from the site of the original specimen. The area was a flooded slough with much submergent grass and weedy growth, approximately 10 by 75 m in size. On that night, 2 specimens were obtained (#UL 6780, 6781) from about 25 calling males. Most frogs were sitting on vegetation at surface level in water less than 1 m in depth.

On 6 July, about 40 individuals were calling in the area. In addition, 10 were calling from a similar flooded area some 100 m distant from the first, and 10 more in a permanently wet area some 10 m in diameter and about 200 m distant from the first location. All 3 areas contained much submergent vegetation. No specimens were taken but recordings were obtained.

Two more individuals were captured on 8 July, one of which is still alive in captivity at this time (18 Feb 1977). About 50 frogs in all were calling on 8 July at the original site, with but 6 at the permanent wet area and none at the third location.

On 10 and 12 July, following several days without rainfall, a total of about 30 calling males was noted at the 3 locations. Some 10 individuals were heard on 14 July and none after that date.

The newly discovered area is in a different drainage system than that involving the other Kentucky population. In addition, it is but 30 km east of the Land Between the Lakes region, one of the most thoroughly studied regions herpetologically within Kentucky. Although we are sure other populations remain undiscovered in parts of Kentucky and Tennessee, it is evident that the range is highly disjunct through those states.

The most significant feature of the distribution of *H. gratiosa* is the absence from southwestern Kentucky along the Mississippi River bottomlands; virtually all Gulf coastal plain species ranging north to Ken-

[1] Contribution No. 186 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

tucky occur in that floodplain. As a result, the overall distribution of the species forms a unique geographical pattern among eastern amphibians. A somewhat similar pattern could be obtained in the mud salamander *Pseudotriton montanus* if the midland race *P. m. diasticus* were relict and disjunct in central Kentucky and Tennessee rather than widespread, but there is no species displaying the particular distributional peculiarities of *H. gratiosa*. Furthermore, the existence of several sizable disjunct breeding populations suggests that the distribution is a natural one, resulting from range contraction and relict populations, rather than possibly being produced through artificial or accidental introductions by man.

Further studies of the Caldwell County population will be conducted in the summer of 1977. Field herpetologists in Kentucky and Tennessee should be alerted to the possible occurrence of this species elsewhere in the region.

LITERATURE CITED

MONROE, B. L., JR., AND R. W. TAYLOR. 1972. Occurrence of the barking treefrog, *Hyla gratiosa*, in Kentucky. J. Herpetol. 6:78.

SCOTT, A. F., AND D. F. HARKER. 1968. First records of the barking treefrog, *Hyla gratiosa* Le Conte, from Tennessee. Herpetologica 24: 82–83.

Articles on Kentucky in the Scientific and Technical Journals of Antebellum Tennessee

James X. Corgan
Austin Peay State University, Clarksville, Tennessee 37040

At least 19 technical or scientific journals were published in Tennessee before 1861 (Corgan 1977). While many are too poorly known to permit analysis of content, several contain articles on the natural history of Kentucky. The following is an annotated bibliography of those articles.

Fanning, Tolbert. 1842. Notes on a short tour of Kentucky. Agriculturist 3:281–282.

Brief notes on agricultural geography.

Loomis, I. Newton. 1846. Geologic encampment. Naturalist 1:337–343, 385–387.

Description of a four-week summer field trip focused on Mammoth Cave.

Martin, Samuel D. 1845. Analysis of Kentucky soil. Agriculturist 6:107–108.

Analyses of 3 samples of soil from Clarke County.

Suddarth, J. B. 1856. Physical and medical topography, etc., of Simpson County; in general applicable to the central region of southern Kentucky. Nashville J. Med. Surg. 11:473–488.

A treatment of physical and cultural geography; includes a list of plants.

To historically oriented students of Kentucky science, those antebellum articles may have academic value. They are now little known because the journals in which they appeared have become very obscure.

Literature Cited

Corgan, J. X. 1977. Tennessee's early technical and scientific journals, 1825–1861. J. Tenn. Acad. Sci. 52:23–26.

Annual Dues The Executive Committee and Board of Directors, in joint session at Georgetown College on 9 April 1977, asked the Secretary to inform the membership of a proposed change in annual dues. In his June 1977 Newsletter, Dr. Seay indicated the following proposed increases to be voted on by the membership at the Sixty-third Annual Meeting at Western Kentucky University on 11 and 12 November 1977: Active membership, $10.00; Student membership, $7.00; Life membership, $100.00; and Contributing membership, $50.00 annually or multiples thereof. Contributing memberships are intended largely, but not solely, for institutions and industrial organizations. It is hoped that one or more of the institutions of higher education in the Commonwealth will use such memberships as an indication of support for the Academy.

Annual Meeting The Annual Meeting of the Kentucky Academy of Science will be held at Western Kentucky University on Friday and Saturday, 11 and 12 November 1977. Dr. Marvin Russell will serve as host. Information on the meeting will be forthcoming with the next Newsletter.

KAS Committees If you are interested in becoming actively associated with the work of the Academy, now is your chance to let it be known! There are a number of Standing Committees to which new members are appointed each year. Those Committees are: Membership, Legislation, Distribution of Research Funds, and Publications. Also, there are other committees that need new and active personnel. If you are interested in serving, or if you know of someone you think can really contribute, please make that willingness or interest known to President Charles Payne, Morehead State University, Morehead, Kentucky 40351, or President Elect Charles E. Kupchella, Cancer Center, University of Louisville, Louisville, Kentucky 40201.

Page Charges At their meeting of 10 September 1977, the Executive Committee of the Kentucky Academy of Science instituted the practice of mandatory page charges of $15.00 per printed page for all papers published in the TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE beginning with Volume 39, Numbers 1–2, to be published in March 1978. The actual costs of publication are in excess of $40.00 per printed page, and there is need to help defray that cost.

Distinguished Scientist Award Dr. Thomas B. Calhoon, Chairman of the Board of Directors of the Kentucky Academy of Science, requests that all nominations for the Distinguished Scientist Award for 1977 be sent to him along with appropriate vitae of the persons nominated. He asks that all such nominations be in his office no later than 10 October 1977. His address is Department of Physiology, Health Sciences Center, University of Louisville, Louisville, Kentucky 40232.

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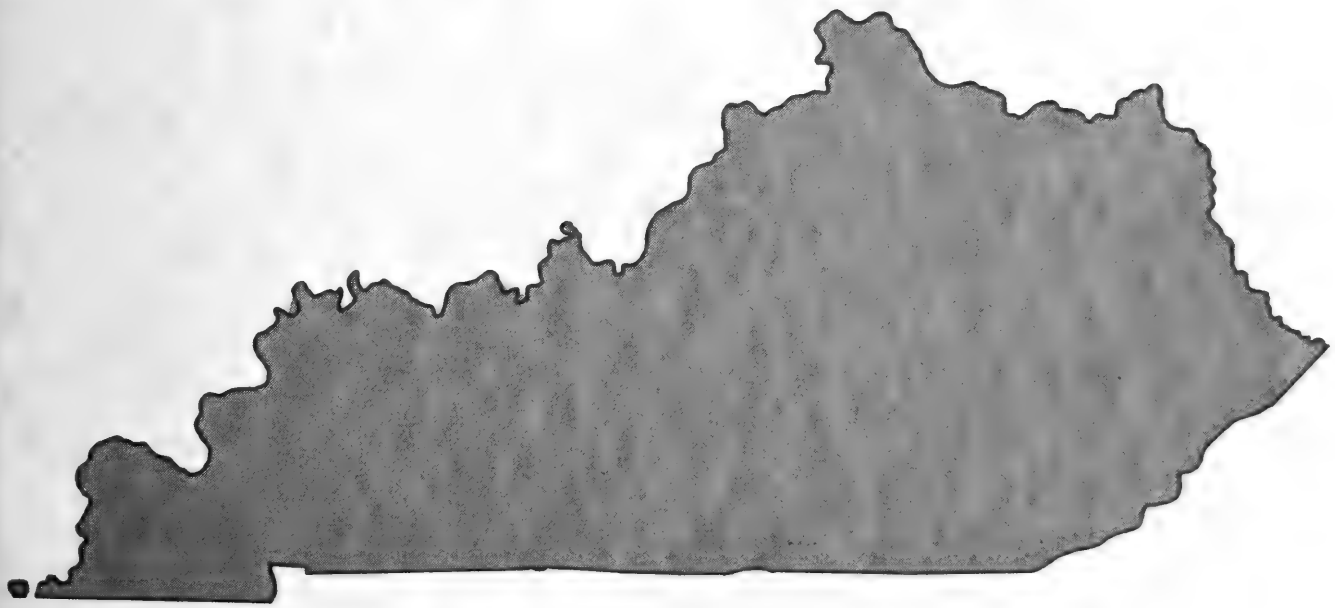

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Structure and Composition of a Climax Mixed Mesophytic Forest System in Laurel County, Kentucky

MARGARET RINGLAND CAMERON III[1] AND JOE E. WINSTEAD
Department of Biology, Western Kentucky University,
Bowling Green, Kentucky 42101

ABSTRACT

Rock Creek Gorge in Laurel County, Kentucky, is a deep, narrow gorge dominated by *Tsuga canadensis*, *Oxydendrum arboreum*, *Betula lenta*, and *Liriodendron tulipifera*, with *Rhododendron maximum* dominating the understory. Analysis of the forest showed the community to be stable and climax. The dominant tree species dominated sapling and seedling size classes. Slight variation was noted between vegetation on east- and west-facing slopes with hemlock having a lower density on west-facing slopes. The study site, composed of 76.5 ha, is estimated to support 329 trees/ha with an average basal area of 23.3 m^2/ha.

INTRODUCTION

Much information has been gathered on the forests of the eastern United States in general, but little information can be found on the forests of the Commonwealth of Kentucky specifically. Rock Creek in Laurel County, Kentucky, was designated as a Natural Area by the U.S. Forest Service in 1939. It became a natural landmark registered by the U.S. Department of the Interior in 1975 providing a reference to a small portion of Kentucky's original vegetation. No extensive compositional studies of the area have been made although Braun (1950) cited Rock Creek as an example of gorge vegetation in hemlock mixed mesophytic forests. In her study, a random sample of 117 trees was taken to determine the composition of the gorge. Winstead and Nicely (1976) sampled the tree flora using the random pairs method but did not make any analysis of size classes of the woody vegetation.

The total natural landmark covers approximately 312 ha (770.64 acres) within the Daniel Boone National Forest adjacent to the Rockcastle River. The area of this study is a deep gorge. Map coordinates and a sketch of the area are included in Winstead and Nicely (1976). Discussions with field workers of the U.S. Forest Service indicated that logging activities in the Rock Creek Gorge took place only at the mouth of the gorge prior to 1938. An absence of stumps, logging trails, and the physical features of extremely steep slopes covered with immense boulders indicates that there has been very little disturbance by man

[1] Present address: Rt. 4, New 96 Highway West, Franklin, TN 37064.

within the boundaries of the area studied in this report.

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MATERIALS AND METHODS

Field work for determination of forest structure and composition was conducted between May and September 1975. To provide analysis of trees, saplings, and seedlings, 3 circular plots were established at each of 10 different sites within the gorge. Five sites were placed on either side of the gorge bisected by Rock Creek. Sites were placed approximately 400 m apart in the upper three-fourths of the gorge so that all sample points were well away from the open end of the gorge and any area that might have been disturbed by logging activity. The concentric circular plots had diameters of 39.9, 28.22, and 19.95 m that provided areas of 0.125, 0.062, and 0.031 ha, respectively. All trees of 10 cm or greater diameter breast height (dbh) were measured and recorded in the 0.125-ha plots. Saplings, designated as woody plant species less than 10 cm dbh and greater than 50 cm in height, were counted and recorded in the 0.062-ha plots. Seedlings, woody plant species less than 50 cm in height, were noted and recorded in the 0.031-ha plots.

Due to the denseness of *Rhododendron* and *Kalmia*, 3-m diameter plots were used to count the stems above ground. Those plots and the sapling plots were then projected to 1 ha and analyzed together.

Data collected in the above manner provided for analysis of total numbers, relative

TABLE 1.—NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), AND IMPORTANCE VALUE (IV) OF TREES SAMPLED IN SUM OF CIRCULAR PLOTS (1.25 HA) IN ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV
Tsuga canadensis	87	0.2106	0.4571	0.1052	0.7729
Oxydendrum arboreum	59	0.1428	0.0612	0.1052	0.3092
Betula lenta	46	0.1113	0.0908	0.1052	0.3073
Liriodendron tulipifera	32	0.0774	0.0797	0.0736	0.2307
Ilex opaca	34	0.0823	0.0248	0.1052	0.2123
Acer rubrum	28	0.0677	0.0493	0.0736	0.1906
Magnolia macrophylla	26	0.0629	0.0220	0.0947	0.1796
Fagus grandifolia	25	0.0605	0.0348	0.0736	0.1689
Quercus rubra	19	0.0460	0.0361	0.0526	0.1347
Quercus alba	12	0.0290	0.0396	0.0421	0.1107
Quercus prinus	10	0.0242	0.0256	0.0315	0.0813
Nyssa sylvatica	8	0.0193	0.0155	0.0315	0.0663
Cornus florida	6	0.0145	0.0025	0.0421	0.0591
Pinus taeda	5	0.0121	0.0256	0.0105	0.0482
Pinus virginiana	5	0.0121	0.0165	0.0105	0.0391
Magnolia acuminata	5	0.0121	0.0060	0.0210	0.0391
Carya glabra	4	0.0096	0.0050	0.0105	0.0251
Aesculus octrandra	1	0.0024	0.0045	0.0105	0.0174
Totals	412	0.9968	0.9966	0.9991	2.9925

density, and relative frequency of the various species in each size class. Diameter measurements of trees provided information for determination of relative dominance and basal area values. An importance value was then calculated for trees by totaling the values for relative density, relative frequency, and relative dominance. Only relative density and relative frequency were calculated for saplings and seedlings. Those values were summed to find the importance of the saplings and seedlings in their respective layers in the gorge.

Soil samples were taken at the center of each site at depths of 0–5 and 5–10 cm. Soil texture analysis followed the technique developed by Bouyocous (1936) using soil hydrometers. Determinations of pH, nitrate nitrogen, phosphorus, and potassium were made utilizing a standard LaMotte soil testing kit.

RESULTS

In Rock Creek Gorge, 18 tree species with individuals 10 cm or greater in diameter were present in the 1.25 ha sampled. Ranked according to importance values (Table 1), the 4 dominant species were: *Tsuga canadensis*, 0.7729; *Oxydendrum arboreum*, 0.3092; *Betula lenta*, 0.3073; and *Liriodendron tulipifera*, 0.2307. *Ilex opaca* had a higher number, relative frequency, and relative density than *L. tulipifera*, but a much smaller relative dominance.

TABLE 2.—NUMBERS OF TREES PER HECTARE AND BASAL AREAS (M^2/HA) FROM SELECTED POSITIONS WITHIN ROCK CREEK GORGE COMPARED WITH THE EARLIER STUDY OF WINSTEAD AND NICELY (1976)

Location	Trees/ha	m^2/ha
Total gorge	329.6	23.3
East-facing slope	300.8	26.7
West-facing slope	358.2	19.9
Four plots closest to earlier study	368.0	26.4
Earlier study total	672.8	47.5

A total of 412 trees having a total basal area of 29.1 m^2 was recorded in the 1.25-ha sampling area. On a per hectare basis, there were 329.6 trees, and the basal area was 23.3 m^2 (Table 2). The mean diameter at breast height of the trees sampled was 24.7 cm.

Twelve species were found on the cooler and wetter east-facing slope in 5 sites that totaled 0.625 ha. The 4 most dominant species were the same as those for the total gorge. The importance values were: *T. canadensis*, 0.9032; *O. arboreum*, 0.3053; *B.*

TABLE 3.—NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), AND IMPORTANCE VALUE (IV) OF TREES SAMPLED IN SUM OF CIRCULAR PLOTS (0.625 HA) ON THE EAST-FACING SLOPE OF ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV
Tsuga canadensis	44	0.2340	0.5473	0.1219	0.9032
Betula lenta	24	0.1276	0.1227	0.1219	0.3722
Acer rubrum	22	0.1170	0.0796	0.1219	0.3185
Oxydendrum arboreum	25	0.1329	0.0505	0.1219	0.3053
Liriodendron tulipifera	22	0.1170	0.0995	0.0975	0.3140
Magnolia macrophylla	19	0.1010	0.0328	0.1219	0.2557
Ilex opaca	19	0.1010	0.0211	0.1219	0.2440
Fagus grandifolia	7	0.0372	0.0091	0.0731	0.1194
Magnolia acuminata	3	0.0159	0.0060	0.0243	0.0462
Quercus alba	1	0.0053	0.0259	0.0243	0.0555
Quercus rubra	1	0.0053	0.0046	0.0243	0.0342
Cornus florida	1	0.0053	0.0004	0.0243	0.0300
Totals	188	0.9995	0.9995	0.9992	2.9982

TABLE 4.—NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), RELATIVE FREQUENCY (RF), AND IMPORTANCE VALUE (IV) OF TREES SAMPLED IN THE SUM OF CIRCULAR PLOTS (0.625 HA) ON THE WEST-FACING SLOPE OF ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RDo	RF	IV
Tsuga canadensis	43	0.1911	0.3361	0.0869	0.6141
Oxydendrum arboreum	34	0.1511	0.1129	0.0869	0.3509
Fagus grandifolia	18	0.0800	0.0693	0.0869	0.2362
Quercus rubra	18	0.0800	0.0839	0.0695	0.2334
Betula lenta	22	0.0977	0.0480	0.0869	0.2326
Ilex opaca	15	0.0666	0.0297	0.0869	0.1832
Quercus alba	11	0.0488	0.0581	0.0521	0.1590
Quercus prinus	10	0.0444	0.0600	0.0521	0.1565
Liriodendron tulipifera	10	0.0444	0.0531	0.0521	0.1496
Nyssa sylvatica	8	0.0355	0.0363	0.0521	0.1239
Magnolia macrophylla	7	0.0311	0.0075	0.0695	0.1081
Pinus taeda	5	0.0222	0.0603	0.0173	0.0998
Acer rubrum	6	0.0260	0.0088	0.0521	0.0869
Cornus florida	5	0.0222	0.0052	0.0521	0.0795
Pinus virginiana	5	0.0222	0.0388	0.0173	0.0783
Carya glabra	4	0.0177	0.0117	0.0173	0.0467
Magnolia acuminata	2	0.0088	0.0060	0.0173	0.0321
Aesculus octandra	1	0.0044	0.0107	0.0173	0.0324
Totals	224	0.9942	1.0364	0.9726	3.0032

lenta, 0.3722; and *L. tulipifera*, 0.3140 (Table 3). There was a total of 188 trees having an average dbh of 26.04 cm and a basal area of 16.7 m^2; on a per hectare basis, the trees totaled 300.8, and the basal area was 26.7 m^2. The largest trees of the gorge were *T. canadensis*, and all were on the east-facing slope. Those 8 trees ranged in diameter from 77.70 to 95.76 cm.

On the drier, west-facing slope, all 18 tree species were present (Table 4). The 6 species restricted to that slope were *Quercus prinus*, *Nyssa sylvatica*, *Pinus tsuga*, *Pinus virginiana*, *Carya glabra*, and *Aesculus octandra*. Of the 4 dominant species, *Tsuga canadensis* and *Oxydendrum arboreum* still ranked first with importance values of 0.6141 and 0.3509, respectively, and were followed by *Fagus grandifolia*, 0.2362, and *Quercus rubra*, 0.2334. *Betula lenta* had a higher relative density than either, but its importance value was only 0.2326. There was a greater number of trees as well as species than on the east-facing slope. The west-facing slope had 224 trees, but the average dbh was only 22.66 cm and the basal area was 12.4 m^2 for the 0.625 ha, or a basal area of 19.9 m^2 and 358.24 trees/ha.

Although not sampled within any of the test plots, 2 additional species, a single large specimen of *Liquidambar styraciflua* and 3 individuals of *Cercis canadensis*, were seen during the field work.

Saplings and shrubs were sampled over a total area of 0.625 ha for the 10 sites. Sixteen species of trees and 4 species of shrubs were found. All species were ranked according to relative density (RD) plus relative frequency (RF) (Table 5). *Tsuga canadensis* (0.1112), *I. opaca* (0.0882), and *F. grandifolia* (0.0882) were the most important trees. *Rhododendron maximum* was the most important shrub as well as the most important woody plant of the understory with a RD + RF value of 0.9432. *Kalmia latifolia* also had a value higher than any sapling, but was found only on the drier, west-facing slope. A few *Castanea dentata* were found, all infected with the

TABLE 5.—NUMBER (N), RELATIVE DENSITY (RD), AND RELATIVE FREQUENCY (RF) OF SAPLING AND SHRUB SPECIES PER HECTARE IN ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Rhododendron maximum	184,000	0.8553	0.0879	0.9432
Kalmia latifolia	30,000	0.1394	0.0329	0.1723
Tsuga canadensis	312	0.0014	0.1098	0.1112
Magnolia macrophylla	56	0.0002	0.0549	0.0551
Ilex opaca	74	0.0003	0.0879	0.0882
Fagus grandifolia	72	0.0003	0.0879	0.0882
Oxydendrum arboreum	95	0.0004	0.0769	0.0773
Acer rubrum	112	0.0005	0.0659	0.0664
Betula lenta	42	0.0002	0.0549	0.0551
Liriodendron tulipifera	27	0.0001	0.0549	0.0550
Cornus florida	21	0.0001	0.0549	0.0550
Clethra acuminata	67	0.0003	0.0439	0.0442
Stewartia ovata	37	0.0001	0.0329	0.0330
Hamamelis virginiana	19	T[1]	0.0329	0.0329
Nyssa sylvatica	8	T	0.0329	0.0329
Quercus alba	8	T	0.0219	0.0219
Quercus rubra	6	T	0.0219	0.0219
Quercus prinus	3	T	0.0219	0.0219
Carya glabra	3	T	0.0111	0.0111
Castanea dentata	2	T	0.0111	0.0111
Totals	215,924	0.9986	0.9993	1.9979

[1] T denotes a value of less than 0.0001.

chestnut blight, and none were over 1 m high. *Stewartia ovata*, a small tree in the understory, was also found in the gorge. The remaining tree species were all found in the canopy and subcanopy. The 2 species of *Pinus* and *A. octandra*, found in the tree size class, were not found in the saplings. *Clethra acuminata* and *Hamamelis virgin-*

TABLE 6.—NUMBER (N), RELATIVE DENSITY (RD), AND RELATIVE FREQUENCY (RF) OF SAPLING AND SHRUB SPECIES PER HECTARE ON THE EAST-FACING SLOPE OF ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Rhododendron maximum	127,574	0.9940	0.1219	1.1159
Tsuga canadensis	160	0.0012	0.1219	0.1231
Ilex opaca	77	0.0006	0.1219	0.1225
Magnolia macrophylla	80	0.0006	0.0976	0.0982
Fagus grandifolia	48	0.0003	0.0976	0.0979
Clethra acuminata	131	0.0010	0.0732	0.0742
Oxydendrum arboreum	105	0.0008	0.0732	0.0740
Betula lenta	67	0.0005	0.0732	0.0737
Acer rubrum	45	0.0003	0.0732	0.0735
Cornus florida	19	0.0001	0.0489	0.0490
Liriodendron tulipifera	13	0.0001	0.0489	0.0490
Stewartia ovata	10	T[1]	0.0244	0.0244
Totals	128,333	0.9995	0.9759	1.9754

[1] T denotes a value of less than 0.0001.

TABLE 7.—NUMBER (N), RELATIVE DENSITY (RD), AND RELATIVE FREQUENCY (RF) OF SAPLING AND SHRUB SPECIES PER HECTARE ON THE WEST-FACING SLOPE OF ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Rhododendron maximum	57,000	0.6465	0.0588	0.7053
Kalmia latifolia	30,000	0.3403	0.0588	0.3991
Tsuga canadensis	467	0.0053	0.0980	0.1033
Fagus grandifolia	96	0.0011	0.0784	0.0795
Oxydendrum arboreum	83	0.0009	0.0784	0.0793
Acer rubrum	179	0.0020	0.0588	0.0608
Ilex opaca	70	0.0008	0.0588	0.0596
Liriodendron tulipifera	42	0.0005	0.0588	0.0593
Hamamelis virginiana	38	0.0004	0.0588	0.0592
Magnolia macrophylla	32	0.0004	0.0588	0.0592
Cornus florida	22	0.0003	0.0588	0.0591
Nyssa sylvatica	16	0.0002	0.0588	0.0590
Quercus rubra	13	0.0001	0.0392	0.0393
Quercus prinus	6	T[1]	0.0392	0.0392
Quercus alba	16	T	0.0222	0.0222
Betula lenta	16	T	0.0196	0.0196
Carya glabra	6	T	0.0196	0.0196
Clethra acuminata	3	T	0.0196	0.0196
Castanea dentata	3	T	0.0196	0.0196
Totals	88,108	0.9988	0.9630	1.9618

[1] T denotes a value of less than 0.0001.

iana were the other shrubs found in the gorge.

On the east-facing slope, the most important saplings and shrubs and their RD + RF values were *R. maximum*, 1.1159; *T. canadensis*, 0.1231; *I. opaca*, 0.1225; and *M. macrophyll*, 0.0982 (Table 6). On the west-facing slope, the 4 major saplings and shrubs and their RD + RF values were *R. maximum*, 0.7053; *K. latifolia*, 0.3391; *T. canadensis*, 0.1033; and *F. grandifolia*, 0.0794 (Table 7). *Oxydendrum arboreum* was also an important species with a value of 0.0793.

According to RD + RF values, the important seedlings in the gorge are *T. canadensis*, 0.3304; *Magnolia* spp., 0.3152; *Acer rubrum*, 0.2584; and *R. maximum*, 0.1911 (Table 8). On the east-facing slope, the predominant seedlings are *Magnolia* spp., 0.4395; *T. canadensis*, 0.3335; *A. rubrum*, 0.3022; and *I. opaca*, 0.2439 (Table 9); and on the west-facing slope are *T. canadensis*, 0.3291; *Magnolia* spp., 0.2306; *A. rubrum*, 0.2289; and *R. maximum*, 0.1588 (Table 10). *Kalmia latifolia*, 0.1542, also has a high importance.

No major differences could be found in the texture of the soil samples between the east- and west-facing slopes. Also, little differences were noted between 0-cm and 5-cm samples. The soil texture tests showed the soil to contain an average of 63.11 percent sand. The average percentage of silt was 17.51 and clay was 13.72.

The pH levels ranged from 3.8 to 4.4, and statistical analysis indicated a highly significant difference (.001 level) between the 3.8 pH of the east-facing slope and the 4.2 of the west-facing slope.

Phosphorus was high in all 16 samples ranging from 168 to 224 kg/ha. Potassium was generally low. The LaMotte soil test measures potassium only for levels of 112 kg/ha or greater. In all but 2 samples the potassium levels were below that limit. At 1 site, the level reached 112 kg/ha in the 5-cm sample. The only difference noted at

TABLE 8.—NUMBER (N), RELATIVE DENSITY (RD), AND RELATIVE FREQUENCY (RF) OF SEEDLINGS SAMPLED IN THE SUM OF CIRCULAR PLOTS (0.312 HA) IN ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Tsuga canadensis	59	0.2092	0.1212	0.3304
Magnolia spp.	59	0.2092	0.1060	0.3152
Acer rubrum	43	0.1524	0.1060	0.2584
Rhododendron maximum	24	0.0851	0.1060	0.1911
Ilex opaca	16	0.0567	0.1212	0.1779
Fagus grandifolia	16	0.0567	0.0454	0.1021
Quercus rubrum	7	0.0248	0.0757	0.1005
Hamamelis virginiana	10	0.0354	0.0606	0.0960
Kalmia latifolia	13	0.0460	0.0454	0.0914
Oxydendrum arboreum	6	0.0212	0.0454	0.0666
Clethra acuminata	5	0.0177	0.0454	0.0631
Nyssa sylvatica	9	0.0319	0.0303	0.0622
Stewartia ovata	7	0.0248	0.0303	0.0551
Liriodendron tulipifera	2	0.0071	0.0303	0.0374
Betula lenta	3	0.0106	0.0151	0.0257
Quercus prinus	2	0.0071	0.0151	0.0222
Sassafras albidum	1	0.0035	0.0151	0.0186
Totals	282	0.9994	1.0145	2.0139

that site from the others was the presence of *P. taeda*, *P. virginiana*, *A. octandra*, and *C. glabra*. In the 0-cm sample of another site, the potassium level measured 173 kg/ha. No species difference occurred at this site. Nitrogen levels were less than 11.2 kg/ha except at 2 sites where the levels were between 11.2 and 22.4 kg/ha.

DISCUSSION

Upon analysis of the data, the forest community was shown to be a stable system. When the 10 most important species of each size class are compared, the data show the forest to be replenishing itself with the same species (Table 11). Eight

TABLE 9.—NUMBER (N), RELATIVE DENSITY (RD), AND RELATIVE FREQUENCY (RF) OF SEEDLINGS SAMPLED IN THE SUM OF CIRCULAR PLOTS (0.156 HA) ON THE EAST-FACING SLOPE IN ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Magnolia spp.	34	0.2656	0.1739	0.4395
Tsuga canadensis	26	0.2031	0.1304	0.3335
Acer rubrum	22	0.1718	0.1304	0.3022
Ilex opaca	9	0.0700	0.1739	0.2439
Rhododendron maximum	14	0.1093	0.1304	0.2397
Fagus grandifolia	2	0.0156	0.0869	0.1025
Quercus rubra	5	0.0390	0.0434	0.0824
Clethra acuminata	5	0.0390	0.0434	0.0824
Stewartia ovata	4	0.0312	0.0434	0.0746
Hamamelis virginiana	4	0.0312	0.0434	0.0746
Totals	125	0.9758	0.9995	1.9753

TABLE 10.—NUMBER (N), RELATIVE DENSITY (RD), AND RELATIVE FREQUENCY (RF) OF SEEDLINGS SAMPLED IN THE SUM OF CIRCULAR PLOTS (0.156 HA) ON THE WEST-FACING SLOPE IN ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Species	N	RD	RF	RD + RF
Tsuga canadensis	33	0.2101	0.1190	0.3291
Magnolia spp.	25	0.1592	0.0714	0.2306
Acer rubrum	21	0.1337	0.0952	0.2289
Rhododendron maximum	10	0.0636	0.0952	0.1588
Kalmia latifolia	13	0.0828	0.0714	0.1542
Ilex opaca	7	0.0445	0.0952	0.1397
Fagus grandifolia	14	0.0891	0.0238	0.1129
Oxydendrum arboreum	6	0.0382	0.0714	0.1096
Hamamelis virginiana	6	0.0382	0.0714	0.1096
Nyssa sylvatica	9	0.0573	0.0476	0.1049
Stewartia ovata	3	0.0191	0.0476	0.0067
Liriodendron tulipifera	2	0.0127	0.0476	0.0603
Betula lenta	3	0.0191	0.0238	0.0429
Quercus rubrum	2	0.0127	0.0238	0.0365
Quercus prinus	2	0.0127	0.0238	0.0365
Sassafras albidum	1	0.0063	0.0238	0.0301
Totals	157	0.9993	0.9520	1.9513

of the first 10 saplings are also among the first 10 trees in importance value, although the order differs. The 2 species that are different in the sapling class are *Cornus florida* and *Stewartia ovata*, usually small trees confined to the subcanopy and understory levels, although *C. florida* was found in the tree class within the gorge. In the seedling class, 8 of the first 10 species were again the same as the trees although the order was not the same. The presence of *Stewartia ovata* in the seedlings makes 9 out of 10 seedlings and saplings the same. In all size classes, *Tsuga* was the most important tree.

Coniferous trees usually are found in a more acid soil than hardwood species, partially because conifers can tolerate more

TABLE 11.—ORDERS OF IMPORTANCE OF TREES[1], SAPLINGS[2], AND SEEDLINGS[3] OF THE 10 MAJOR TREE SPECIES WITHIN ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Trees	Saplings	Seedlings
Tsuga canadensis	*Tsuga canadensis*	*Tsuga canadensis*
Oxydendrum arboreum	*Magnolia macrophylla*	*Magnolia* spp.
Betula lenta	*Ilex opaca*	*Acer rubrum*
Ilex opaca	*Fagus grandifolia*	*Fagus grandifolia*
Liriodendron tulipifera	*Oxydendrum arboreum*	*Quercus rubra*
Acer rubrum	*Acer rubrum*	*Ilex opaca*
Magnolia macrophylla	*Betula lenta*	*Oxydendrum arboreum*
Fagus grandifolia	*Liriodendron tulipifera*	*Nyssa sylvatica*
Quercus rubra	*Cornus florida*	*Stewartia ovata*
Quercus alba	*Stewartia ovata*	*Betula lenta*

[1] Trees with diameter of 10 cm dbh or greater.
[2] Saplings having a diameter of less than 10 cm dbh and a height of 50 cm or greater.
[3] Seedlings—woody tree and shrub species having a height less than 50 cm.

TABLE 12.—TREE SPECIES REPORTED IN 3 STUDIES OF THE ROCK CREEK GORGE, LAUREL COUNTY, KENTUCKY

Present study 412 trees	Braun (1950) 117 trees	Winstead and Nicely (1976) 100 trees
Tsuga canadensis	*Tsuga canadensis*	*Tsuga canadensis*
Oxydendrum arboreum	*Fagus grandifolia*	*Liriodendron tulipifera*
Betula lenta	*Liriodendron tulipifera*	*Betula lenta*
Liriodendron tulipifera	*Acer rubrum*	*Acer rubrum*
Ilex opaca	*Quercus rubra*	*Quercus rubra*
Acer rubrum	*Betula lenta*	*Ilex opaca*
Magnolia macrophylla	*Ilex opaca*	*Nyssa sylvatica*
Fagus grandifolia	*Castanea dentata*	*Prunus serotina*
Quercus rubra	*Nyssa sylvatica*	*Fagus grandifolia*
Quercus alba	*Quercus montana*[1]	*Quercus alba*
Quercus prinus[1]	*Oxydendrum arboreum*	*Magnolia macrophylla*
Nyssa sylvatica	*Magnolia macrophylla*	*Carpinus caroliniana*
Cornus florida		*Cornus florida*
Pinus taeda		
Pinus virginiana		
Carya ovata		
Aesculus octandra		
Magnolia acuminata		

[1] Same species according to Radford et al. (1968).

acid soils and partially because of their presence. In sandy soils, such as that in the gorge, cations are easily leached and replaced by hydrogen ions. Also, plant litter from certain species, especially those of Pinaceae, yield acidic material when they decompose (Daubenmire 1959). In the soil of the gorge, there was a highly significant difference between the pH of the east-facing and west-facing slopes. The pH was lowest on the east-facing slope (3.8), and the only conifer present (*Tsuga canadensis*) had the highest relative dominance (0.5473). On the west-facing slope, the pH was 4.4, and 3 species of conifers collectively had a relative dominance of 0.4352, while the hardwoods had a relative dominance of 0.5639.

Other studies involving Rock Creek Gorge were done with different techniques and smaller samples. In the study by Braun (1950), 117 trees were randomly sampled and recorded. Winstead and Nicely (1976) used 2 750-m transect lines to sample 100 trees using a random pairs method. The 3 studies show a difference in the data collected (Table 12). In a comparison of number of species, Braun found 12, 11 of which were the same as in the present study. The other single species reported by Braun, but absent in the present analysis, was *Castanea dentata* which has been eliminated by chestnut blight. Dead, fallen chestnut trees still remain in the gorge. Winstead and Nicely (1976) found 13 species of trees within the gorge. Eleven of those species were found in the present study; *Prunus serotina* and *Carpinus caroliniana* were not found.

Basal areas of the present study were compared with those reported by Winstead and Nicely (1976) (Table 2). The 2 techniques gave different results. An analysis of the 4 plots nearest the earlier study showed 368 trees/ha with a basal area of 26.4 m^2. Those figures are higher than for the total gorge (329.6 trees with 23.3 m^2/ha basal area). The numbers are less than those in the preliminary study that had 672.3 trees/ha with a basal area of 47.5 m^2. The data show a pattern of decreasing numbers with increasing size of the area sampled.

The basal area data from Rock Creek

Gorge do not match the predicted value of 30 m^2/ha as proposed by Held and Winstead (1975) being an indication of climax status in mesic forest systems. Their proposal was developed by comparing basal area data from various studies of forests primarily in Kentucky and Indiana. Those forest ecosystems were not confined to such a narrow gorge as Rock Creek; thus, the physiography of the area might be limiting in some way to tree growth.

Braun (1950) found that the pattern of vegetation in Rock Creek Gorge with hemlock dominant accompanied by dense thickets of *Rhododendron* was typical of the narrowest gorges of the Cumberland Plateau. She also noted the greater importance of oak on the drier slopes. In Rock Creek, the importance value of the sum of the 3 species of oak on the west-facing slope was 0.5489, just below that of hemlock (0.6141). On the other slope, only 1 species of oak was present having a value of 0.0535, while that of hemlock was 0.9104.

Lilley Cornett Woods in Letcher County is a virgin area in southeastern Kentucky on the Cumberland Plateau (Martin 1975). The area contains several hemlock communities on lower northeastern and northwestern slopes. *Tsuga canadensis* accounted for 60 percent of the importance value and *Fagus grandfolia* was the only other important constituent. The northwestern slope had smaller trees with the highest density of 478 stems/ha; the northeastern slope had 321 stems/ha. The pattern is the same as that in Rock Creek Gorge. Also, as in Rock Creek, oak became a more important constituent on the northwestern slope. A greater number of tree species was present on the northwestern slope of Lilley Cornett Woods than in Rock Creek Gorge. Fifteen species were found on the northeastern slope and 18 on the northwestern slope compared with 12 on the eastern slope and 18 on the western slope in Rock Creek. Basal areas were higher in the woods than the gorge. Martin (1975) reported basal areas of 42.4 m^2/ha on the northeastern slope and 22.4 m^2/ha on the northwestern slope of Lilley Cornett Woods compared with 26.7 m^2/ha on the eastern and 19.9 m^2/ha on the western in the gorge. That difference may be due to differences in methods. Martin used 12.4 cm dbh as the smallest tree size instead of the 10 cm dbh limit used in Rock Creek. In spite of that difference, the pattern is still the same. The greatest basal area is on the eastern slopes.

In Lilley Cornett Woods, beech was a more important constituent of the forest composition than in Rock Creek Gorge. Braun (1950) found the same to be true of wider gorges where beech occupied the valley floor. The pattern was present at Yahoo Falls in McCreary County, Kentucky, although that area is not covered by a virgin forest (Braun 1950).

No other virgin hemlock–mixed mesophytic forests have been studied in Kentucky. Areas of secondary growth with the same hemlock–mixed mesophytic forest are present in Red River Gorge, but to our knowledge no compositional studies have been done there. In 1973, Herman and See reported on secondary succession after a fire in the hemlock–mixed mesophytic forest of "Tight Holler" in Wolfe County. After 47 years, tulip poplar was dominant, and hemlock was present only in the shrub layer.

Rock Creek Gorge is a good site for more specific ecological studies of virgin vegetation. Also, the rim of the gorge is secondary growth with 1 plot that was clearcut in 1965 by the U.S. Forest Service. The plot has since been abandoned and is a possible site of the study of successional patterns of that area.

The present study gives a more complete picture of vegetational structure and community composition than would be expected to develop within similar gorge habitats in the Cumberland Plateau of Kentucky. Such information may be of considerable value in future plans of wilderness management and development of potential recreational sites. Another point of significance is that such a protected area as Rock Creek, once inventoried, provides a potential pool of genetic stock representing species that now or in the future might have great economic

value in reforestation, timber production, and wildlife management. It is also hoped the data presented here may provide baseline information for comparison with other climax forest systems within the central and eastern United States in relation to stability of forest ecosystems and species diversity.

LITERATURE CITED

BRAUN, E. L. 1950. Deciduous Forests of Eastern North America. Hafner Publishing Co., New York, N.Y. 596 pp.

BOUYOUCOS, G. J. 1936. Directions for making mechanical analysis of soils by the hydrometer method. Soil Science 42:225–229.

DAUBENMIRE, R. F. 1969. Plants and Environment. John Wiley & Sons, Inc., New York, N.Y. 422 pp.

HELD, M. E., AND J. E. WINSTEAD. 1975. Basal area and climax status in mesic forest systems. Ann. Bot. 39:1147–1148.

HERMAN, T., AND M. G. SEE. 1973. Secondary succession following fire in "Tight Holler," Kentucky. Castanea 38:275–285.

MARTIN, W. H. 1975. The Lilley Cornett Woods: A stable mixed mesophytic forest in Kentucky. Bot. Gaz. 136:171–183.

RADFORD, A. E., H. E. AHLES, AND C. R. BELL. 1968. Manual of the Vascular Flora of the Carolinas. Univ. N. Carolina Press, Chapel Hill, N.C. 1183 pp.

WINSTEAD, J. E., AND K. A. NICELY. 1976. A preliminary study of a virgin forest tract of the Cumberland Plateau in Laurel County, Kentucky. Trans. Ky. Acad. Sci. 37(1–2): 29–32.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 12–22

Vegetation of the Boone County Cliffs Nature Preserve, a Forest on a Kansan Outwash Deposit in Northern Kentucky

William S. Bryant
Department of Biology, Thomas More College,
Ft. Mitchell, Kentucky 41017

Abstract

Four distinct local communities were recognized and related to aspect and disturbance at the 20.24-hectare Boone County Cliffs Nature Preserve on Kansan outwash deposits in northern Kentucky. The dominant tree species in each community were: *Acer saccharum, Quercus muhlenbergii, Q. rubra,* and *Ulmus rubra* in the maple–oak–elm community; *Ulmus rubra, Acer saccharum, Fraxinus americana, Quercus muhlenbergii, Q. rubra,* and *Robinia pseudo-acacia* in the elm–maple–locust community; *Acer saccharum, Tilia americana, Fagus grandifolia,* and *Fraxinus americana* in the maple–basswood–beech community; and *Acer saccharum, Fagus grandifolia, Fraxinus americana, Quercus rubra,* and *Q. alba* in the maple–beech–oak community. The vegetation of the forest differs greatly from the hydromesophytic forests of the Illinoian till plain, but compares somewhat to the slope and ravine forests on other Illinoian deposits.

Introduction

Several authors have reported on the vegetation of the glaciated tristate area of northern Kentucky (Nelson 1918, Braun 1950, Keith 1968, Held and Winstead 1976), southwestern Ohio (Braun 1916, 1917, 1936, 1950; Cobbe 1943), and southeastern Indiana (Gordon 1936, Chapman 1942, Keller 1946, Beals and Cope 1964). All those studies concerned vegetation on Illinoian till except that of Keith (1968) who did not differentiate between the various Pleistocene drift deposits. No reports are available for the areas of Kansan outwash recently identified in northern Kentucky (Ray 1966, 1974) that filled ancient and abandoned tributaries to the Ohio River.

In this paper, the vegetation on Kansan outwash at the Boone County Cliffs Nature Preserve is compared with that of areas of Illinoian till. The Preserve, purchased by the Kentucky Chapter of The Nature Conservancy, is known locally as the Cliffs or Enchanted Valley. Sutton (1877, 1879) referred to the area as the Middle Creek Conglomerate.

The Study Area

The 20.24-ha Boone County Cliffs Nature Preserve lies off Middle Creek Road approximately 14.2 km west of Burlington, in western Boone County, Kentucky. While old growth forest predominates the Preserve, some logging occurred about 60 years ago and some trees were selectively cut just prior to acquisition by The Nature Conservancy (however, my data were collected prior to that most recent logging).

Elevations in the Preserve range from 198 to 259 m above mean sea level. Large conglomerate cliffs and boulders outcrop on the slopes (Fig. 1). Ray (1974) stated that the Middle Creek conglomerate is composed of cemented sand, gravels, and cobbles of limestone and a few crystalline rocks and quartzite. The area that includes the conglomerate is now deeply eroded, especially by Middle Creek, to narrow valleys with rugged precipitous walls 18.3 m or more high. Soils are Jessup silt loam and Cynthiana flaggy clay loam (Weisenberger et al. 1973) and are derived from weathering of the conglomerate and colluvial action.

Wet areas resulting from the seepage of water from the interior of the conglomerate rock are abundant and present throughout the year. A springfed stream passes through the ravine that separates the north- and south-facing slopes.

The climate is temperate and humid. The average temperature is 12.2 C and the aver-

FIG. 1. Large conglomerate outcrop on the south-facing slope of the Boone County Cliffs Nature Preserve, Boone County, Kentucky.

age annual rainfall is 101.6 cm (Weisenberger et al. 1973).

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METHODS AND MATERIALS

Vegetation was sampled from March 1972 to October 1976. Trees were sampled in 0.04-ha circular plots, saplings in 0.01-ha circular plots, and seedlings in 0.004-ha circular plots. Shrubs were sampled in the latter 2 sized plots.

Woody plants with diameters breast height (dbh) of 8.9 cm (3.5 inches) or greater were classed as trees. Seedlings and saplings were placed in appropriate size classes determined with a sampling template. Seedlings in Class 1 were woody plants from 15.2 cm to 1.37 m high (6 inches–4.5 feet); those in Class 2 were over 1.37 m high with diameters at ground level less than 1.27 cm (0.5 inch). All sapling size classes were 1.37 m or more in height. Saplings in Class 3 were from 1.27 to 3.81 cm (0.5–1.5 inches) in diameter; Class 4 were from 3.81 to 6.35 cm (1.5–2.5 inches) in diameter; and Class 5 were from 6.35 to 8.9 cm (2.5–3.5 inches) in diameter. A total of 29 plots for each vegetational category was sampled. Plots were spaced at 33-m intervals along straight-line transects through the communities sampled.

The relative frequency (RF), relative density (RD), relative dominance (RDo), and importance value (IV) for each tree species were determined. Numbers of seedlings, saplings, and shrubs per hectare were determined.

TABLE 1.—THE NUMBER (N), RELATIVE FREQUENCY (RF), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF ALL TREE SPECIES AT THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

	N	RF	RD	RDo	IV
Acer saccharum	216	17.31	40.91	20.83	79.05
Ulmus rubra	72	8.33	13.64	11.84	33.81
Fraxinus americana	43	11.54	8.14	10.01	29.69
Fagus grandifolia	14	5.77	2.65	12.23	20.65
Quercus rubra	22	7.69	4.17	8.11	19.97
Quercus muhlenbergii	33	3.85	6.25	7.26	17.36
Tilia americana	16	3.85	3.03	7.51	14.39
Celtis occidentalis	16	4.49	3.03	2.36	9.88
Robinia pseudo-acacia	12	3.85	2.27	3.41	9.53
Liriodendron tulipifera	9	5.13	1.70	2.49	9.32
Carya cordiformis	8	3.85	1.52	3.73	9.10
Juglans nigra	9	3.21	1.70	1.98	6.89
Quercus alba	6	1.92	1.14	2.82	5.88
Ulmus americana	6	2.56	1.14	2.12	5.82
Cercis canadensis	12	2.56	2.27	0.47	5.30
Carpinus caroliniana	7	3.21	1.33	0.27	4.81
Carya ovata	7	2.56	1.33	0.37	4.26
Fraxinus quadrangulata	7	1.92	1.33	0.64	3.89
Ostrya virginiana	5	1.92	0.95	0.19	3.06
Aesculus glabra	2	1.28	0.38	0.14	1.80
Platanus occidentalis	1	0.65	0.19	0.73	1.56
Gymnocladus dioicus	2	0.64	0.38	0.30	1.32
Carya glabra	1	0.64	0.19	0.08	0.91
Acer negundo	1	0.64	0.19	0.07	0.90
Cornus florida	1	0.64	0.19	0.03	0.86
Totals	528	100.00	100.02	99.99	300.01

Because of local differences in habitat, such as aspect and disturbance, the forest was divided into 4 sampling areas: south-facing slope, ridge atop the south-facing slope, north-facing slope, and ridge atop the north-facing slope. No quantitative determinations of herbs were made, however, notes on the herbaceous composition were taken. Soil samples were taken from 20 sites and the soil texture was determined with a hydrometer.

Nomenclature for all plant species follows Mohlenbrock and Voigt (1959).

ANALYSIS OF COMMUNITIES

Distinct local communities were recognized and probably were related to aspects and disturbances. The 4 community types were: maple–oak–elm on the south-facing slope, elm–maple–locust on the ridge atop the south-facing slope, maple–basswood–beech on the north-facing slope, and maple–beech–oak on the ridge atop the north-facing slope. In addition to the major community types, a small stand of *Liriodendron tulipifera* was present in the ravine between the slopes. A list of the kinds of trees in the entire Preserve is presented in Table 1, and the average basal area values for the dominant tree species in each community are listed in Table 2.

Average values for soil samples at 20 locations throughout the Preserve were: sand (40.37%), clay (23.21%), and silt (36.42%). Local differences regarding soil

TABLE 2.—AVERAGE BASAL AREA (CM^2) FOR INDIVIDUAL TREES OF 8 SPECIES IN THE 4 COMMUNITIES AT THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

	South-facing slope	South ridge	North-facing slope	North ridge
Acer saccharum	270.84	197.18	229.43	472.72
Quercus rubra	1,549.87	421.44	902.94	1,653.01
Fraxinus americana	1,006.33	553.86	856.95	687.70
Ulmus rubra	321.21	540.06	1,259.10	
Quercus muhlenbergii	848.95	365.07		
Robinia pseudo-acacia	476.53	994.98		
Tilia americana			1,642.11	497.10
Fagus grandifolia			3,511.57	2,389.85

textures probably were not great enough to modify plant distributions.

Maple–Oak–Elm Community

The south-facing slope was the driest habitat in the Preserve due to its exposure. The upper half of the slope was decidedly xeric. *Acer saccharum* (IV 61.42) was the most prominent tree, although being most abundant on the lower portions of the slope (Table 3). Oaks, *Quercus muhlenbergii* (IV 43.82) and *Q. rubra* (IV 28.30), ranked second and third, respectively, while *Q. alba* (IV 5.16) ranked thirteenth. Combined, the oaks had an importance value of 77.28. Other important associated trees included *Ulmus rubra, Juglans nigra, Fraxinus americana,* and *Celtis occidentalis. Fraxinus quadrangulata* was confined to the upper slope, especially rooted in the large

TABLE 3.—THE NUMBER (N), RELATIVE FREQUENCY (RF), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF ALL TREE SPECIES ON THE SOUTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

Species	N	RF	RD	RDo	IV
Acer saccharum	51	13.46	32.90	15.60	61.42
Quercus muhlenbergii	23	7.69	14.84	21.29	43.82
Quercus rubra	8	9.62	5.16	13.52	28.30
Ulmus rubra	18	7.69	11.61	6.30	25.60
Juglans nigra	9	9.62	5.81	6.89	22.32
Fraxinus americana	8	7.69	5.16	8.78	21.63
Celtis occidentalis	10	5.79	6.45	5.80	18.02
Liriodendron tulipifera	6	9.62	3.87	2.82	16.31
Ulmus americana	5	5.77	3.23	4.71	13.71
Carya cordiformis	2	3.85	1.29	6.83	11.97
Cercis canadensis	7	3.85	4.52	1.27	9.64
Robinia pseudo-acacia	2	3.85	1.29	1.04	6.18
Quercus alba	1	1.92	0.65	2.59	5.16
Platanus occidentalis	1	1.92	0.65	2.55	5.12
Acer negundo	1	1.92	0.65	0.24	2.81
Fraxinus quadrangulata	1	1.92	0.65	0.17	2.74
Carpinus caroliniana	1	1.92	0.65	0.09	2.66
Aesculus glabra	1	1.92	0.65	0.07	2.64
Totals	155	100.00	100.03	100.02	300.05

TABLE 4.—SEEDLINGS (SIZE CLASSES 1, 2) AND SAPLINGS (SIZE CLASSES 3, 4, 5) PER HECTARE OF ALL SHRUB AND TREE SPECIES ON THE SOUTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

	Size class				
	1	2	3	4	5
Shrubs					
Staphylea trifolia	164.65	136.21	21.93		
Lindera benzoin	3,265.88	3,101.31	406.17	186.61	
Asimina triloba	1,180.09	741.00	43.89		
Seedlings–saplings					
Acer saccharum	686.09	356.77	164.67	32.93	10.97
Quercus rubra	82.33	54.88	43.89	43.89	
Fraxinus americana		137.21	65.87	10.97	
Cercis canadensis	439.09	164.67	186.61	43.89	
Ostrya virginiana	439.09	54.88	10.97		
Carya cordiformis	137.21				
Carpinus caroliniana	27.44		21.93	10.97	
Acer negundo	109.77	54.88			
Fraxinus quadrangulata	219.53	137.21	32.93		
Prunus serotina	164.65	27.44	21.93		
Fagus grandifolia	27.44			10.97	
Platanus occidentalis		27.44			
Liriodendron tulipifera	164.65			10.97	
Ulmus rubra	301.88	109.77			
Celtis occidentalis	82.33	27.44			
Aesculus glabra			21.93	10.97	
Qercus muhlenbergii			10.97		

conglomerate outcrops that were difficult to sample.

Cercis canadensis was the major understory tree. Shrubs, *Lindera benzoin*, *Asimina triloba*, and *Staphylea trifolia*, were most abundant on the lower slope and near the stream, yet *A. triloba* did extend upslope wherever water seepage occurred.

Of the canopy trees, seedlings and saplings of *A. saccharum* were the most abundant (Table 4). Seedlings and saplings of most of the dominant trees were present, but only *A. saccharum* reached tree replacement size.

Elm–Maple–Locust Community

The ridge atop the south-facing slope was cleared approximately 60 years ago and an old farm road crossed the ridge. Remnants of the early successional stages, *Ulmus rubra* and *Robinia pseudo-acacia*, were still present and ranked first (IV 91.48) and fourth (IV 33.02), respectively (Table 5). *A. saccharum*, *F. americana*, and the oaks, *Q. muhlenbergii* and *Q. rubra*, were other important trees, however, those 4 species were smaller there than elsewhere in the Preserve reflecting a more recent establishment. Entire black locust trees and portions of others were dead and dying. The replacement of *R. pseudo-acacia* by *A. saccharum*, *F. americana*, and the oaks was in advanced condition. Those latter species were of Class 5 (Table 6). *U. rubra* was reproducing, but *R. pseudo-acacia* was not. *F. quadrangulata* was most abundant near the edge of the conglomerate cliffs and its seedlings and saplings extended throughout the ridge.

An understory of *Cercis canadensis* was developing under the new canopy. *Asimina*

TABLE 5.—THE NUMBER (N), RELATIVE FREQUENCY (RF), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF ALL TREE SPECIES ON THE RIDGE ATOP THE SOUTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

Species	N	RF	RD	RDo	IV
Ulmus rubra	50	16.67	33.56	41.25	91.48
Acer saccharum	38	16.67	25.50	11.45	53.62
Fraxinus americana	15	13.89	10.07	12.69	36.65
Robinia pseudo-acacia	10	11.11	6.71	15.20	33.02
Quercus muhlenbergii	10	5.56	6.71	5.58	17.85
Quercus rubra	6	8.33	4.03	3.86	16.22
Carya cordiformis	3	5.56	2.01	2.28	9.85
Celtis occidentalis	3	5.56	2.01	2.10	9.67
Fraxinus quadrangulata	5	2.78	3.36	2.55	8.69
Carya ovata	2	5.56	1.34	0.81	7.70
Cercis canadensis	4	2.78	2.68	0.41	5.87
Gymnocladus dioicus	2	2.78	1.34	1.45	5.57
Carya glabra	1	2.78	0.67	0.38	3.83
Totals	149	100.03	99.99	100.00	300.02

TABLE 6.—SEEDLINGS (SIZE CLASSES 1, 2) AND SAPLINGS (SIZE CLASSES 3, 4, 5) PER HECTARE OF ALL SHRUB AND TREE SPECIES ON THE RIDGE ATOP THE SOUTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

	Size class				
	1	2	3	4	5
Shrubs					
Asimina triloba	41.15		49.40		
Staphylea trifolia	205.83		16.47		
Symphoricarpos orbiculatus	411.67				
Rubus sp.	1,770.15				
Seedlings–saplings					
Acer saccharum	247.00	82.33	312.87	214.07	32.93
Quercus muhlenbergii	82.33		131.73	16.47	16.47
Quercus rubra	82.33		214.07	32.93	16.47
Ulmus rubra	823.33	82.33	65.87	16.47	16.47
Cercis canadensis	82.33		181.13	32.93	16.47
Ostrya virginiana	123.50		16.47		
Fraxinus quadrangulata	1,111.50	782.17	230.53		
Fraxinus americana	164.65	41.15	115.27		
Carya cordiformis	370.50	123.50	16.47		
Celtis occidentalis	946.83	247.00	131.73		
Acer negundo	41.15	41.15	16.47		
Ulmus americana	41.15				
Juniperus virginiana	41.15				
Aesculus glabra			16.47		
Gymnocladus dioicus			32.93		
Carya glabra			16.47		

TABLE 7.—THE NUMBER (N), RELATIVE FREQUENCY (RF), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF ALL TREE SPECIES ON THE NORTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

Species	N	RF	RD	RDo	IV
Acer saccharum	61	19.05	50.00	16.73	85.78
Tilia americana	14	11.90	11.48	27.49	50.87
Fagus grandifolia	5	7.14	4.10	20.99	32.23
Fraxinus americana	11	7.14	9.02	11.27	27.43
Ulmus rubra	4	7.14	3.28	6.02	16.44
Carpinus caroliniana	6	9.52	4.92	0.94	15.38
Carya cordiformis	3	4.76	2.46	4.98	12.20
Quercus rubra	3	4.76	2.46	3.24	10.46
Liriodendron tulipifera	2	4.76	1.64	2.50	8.90
Ostrya virginiana	4	4.76	3.28	0.65	8.69
Celtis occidentalis	3	4.76	2.46	1.01	8.23
Ulmus americana	1	2.38	0.82	2.92	6.12
Aesculus glabra	1	2.38	0.82	0.45	3.65
Carya ovata	1	2.38	0.82	0.35	3.55
Fraxinus quadrangulata	1	2.38	0.82	0.26	3.46
Cornus florida	1	2.38	0.82	0.12	3.32
Cercis canadensis	1	2.38	0.82	0.08	3.28
Totals	122	99.97	100.02	100.00	299.99

triloba and *Staphylea trifolia* were present where slight depressions in soil allowed water accumulation. Remnants of the past clearing association, *Symphoricarpos orbiculatus* and *Rubus* sp. persisted in the tracks of the farm road.

Maple–Basswood–Beech Community

The vegetation of the north-facing slope was a mixed mesophytic association with *A. saccharum* (IV 85.78), *Tilia americana* (IV 50.87), and *Fagus grandifolia* (IV 32.23) as the dominant trees (Table 7). *F. americana* and *U. rubra* were major associates. The understory was composed of *Carpinus caroliniana* and *Ostrya virginiana.*

The shrub layer was composed of *Lindera benzoin, Asimina triloba,* and *Staphylea trifolia.* All of those species ranged high up the slope and were not confined to seepage areas. A few individuals of *Hydrangea arborescens* were present, but were not recorded from sample plots. Of the dominant tree species, replacement to tree size was by *A. saccharum, T. americana,* and *F. americana,* however, saplings up to Class 3 of *Fagus grandifolia* were present (Table 8).

Maple–Beech–Oak Community

The ridge atop the north-facing slope was also dominated by *A. saccharum* (IV 127.53), with major associated canopy trees being *F. grandifolia* (IV 59.30), and *F. americana* (IV 39.78) (Table 9). *Q. rubra* and *Q. alba* ranked fourth and fifth, respectively, but as a composite the oaks had an importance value of 44.17.

The trees were widely spaced and there was no well-defined subcanopy or shrub layer. Seedlings and saplings of *A. saccharum* and *F. grandifolia* were present to tree replacement size (Table 10).

Shortly after that ridge community was sampled, many of the oaks were logged.

Hummock of Tulip Poplar

Near the head of the stream that passed through the ravine was a small stand of *Liriodendron tulipifera.* The soil was deeper there than elsewhere in the Preserve.

TABLE 8.—SEEDLINGS (SIZE CLASSES 1, 2) AND SAPLINGS (SIZE CLASSES 3, 4, 5) PER HECTARE OF ALL SHRUB AND TREE SPECIES ON THE NORTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

	Size class				
	1	2	3	4	5
Shrubs					
Asimina triloba	2,223.00	2,037.75	61.75		
Lindera benzoin	185.25	185.25	37.05		
Staphylea trifolia	339.63	123.50	24.70		
Seedlings–saplings					
Acer saccharum	617.50	648.38	135.85	86.45	24.70
Tilia americana	185.25	123.50	12.35		12.35
Fraxinus americana	61.75	92.63			12.35
Carpinus caroliniana	61.75	30.88	12.35		
Fagus grandifolia	92.63	61.75	61.75		
Ulmus rubra	185.25	123.50			
Quercus rubra		30.88			
Cercis canadensis	92.63		61.75	12.35	
Acer negundo	92.63			12.35	
Liriodendron tulipifera	30.88				
Carya cordiformis	61.75				
Fraxinus quadrangulata		30.88			
Aesculus glabra		61.75			

That stand apparently was the seed source of the tulip poplars of the slopes.

DISCUSSION

No comparable studies of vegetation on Kansan outwash have been reported, although Keith (1968) undoubtedly included some areas in his study; however, because of the weathered nature of the areas he sampled, he made no distinctions between till deposits. Since there is more literature for vegetation of Illinoian till available comparisons are to that area.

When all sampling areas are combined, the forest of the Boone County Cliffs

TABLE 9.—THE NUMBER (N), RELATIVE FREQUENCY (RF), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF ALL TREE SPECIES ON THE RIDGE ATOP THE NORTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

Species	N	RF	RD	RDo	IV
Acer saccharum	66	23.08	64.71	39.74	127.53
Fagus grandifolia	9	23.08	8.82	27.40	59.30
Fraxinus americana	9	23.08	8.82	7.88	39.78
Quercus rubra	5	7.69	4.90	10.53	23.12
Quercus alba	1	7.69	4.90	8.46	21.05
Liriodendron tulipifera	1	3.85	0.98	4.18	9.01
Carya ovata	4	3.85	3.92	0.44	8.21
Tilia americana	2	3.85	1.96	1.27	7.08
Ostrya virginiana	1	3.85	0.98	0.09	4.92
Totals	102	100.02	99.99	99.99	300.00

TABLE 10.—SEEDLINGS (SIZE CLASSES 1, 2) AND SAPLINGS (SIZE CLASSES 3, 4, 5) PER HECTARE OF ALL SHRUBS AND TREE SPECIES ON THE RIDGE ATOP THE NORTH-FACING SLOPE OF THE BOONE COUNTY CLIFFS NATURE PRESERVE, BOONE COUNTY, KENTUCKY

	Size class				
	1	2	3	4	5
Seedlings–saplings					
Acer saccharum	494.00	247.00	131.73	49.40	131.73
Fagus grandifolia	329.33	41.17	279.93	32.93	16.47
Ostrya virginiana	617.50	370.50	148.20		16.47
Cornus florida	41.17		65.87	131.73	
Carya cordiformis	247.00	82.33	49.40		
Quercus rubra	205.83	164.67	98.80		
Fraxinus americana	164.67				
Fraxinus quadrangulata	82.33	41.17	16.47		
Ulmus rubra	494.00		16.47		
Celtis occidentalis		41.17			
Sassafras albidum		41.17			

Nature Preserve shows some similarities as well as striking differences to those on Illinoian till, in particular the Dinsmore's Woods (Held and Winstead 1976). In both forests, *Acer saccharum* ranked first in importance value, 79.05 at the Preserve to 91.94 at Dinsmore's Woods. *Fraxinus americana* ranked third at the Preserve (IV 29.69) and second at Dinsmore's Woods (IV 44.48) while *Ulmus rubra* ranked second at the Preserve (IV 33.81) and fourth at Dinsmore's Woods (IV 22.93). The Preserve forest was decidedly more mesic than Dinsmore's Woods when the respective importance values of the following species are compared: *Fagus grandifolia*, 20.65 to 6.91; *Tilia americana*, 14.39 to 5.17; *Quercus rubra*, 19.71 to 7.81; and *Liriodendron tulipifera*, 9.32 to 0. The importance values for *Q. muhlenbergii*, 17.36 to 5.38; *Q. alba*, 5.88 to 17.87; and *Celtis occidentalis*, 9.88 to 29.88, reflect other differences. Keith (1968) felt that a high importance for *C. occidentalis*, such as that at Dinsmore's Woods indicated a disclimax. Basal area values were very similar, 27.2 m^2/ha at the Preserve to 28.1 m^2/ha at Dinsmore's Woods. The differences between the forests probably are the results of different soils, weathered conglomerate, and colluvium at the Preserve and a Wisconsin loess cap at Dinsmore's Woods, in conjunction with a greater number of microhabitats at the Preserve.

Local habitat factors result in distinct communities at the Preserve with only 3 tree species, *A. saccharum*, *F. americana*, and *Q. rubra*, in each of the 4 community types. Cobbe (1943) noted the establishment of local communities at Cabin Run, Ohio, as a result of microenvironmental differences.

The vegetation of the south-facing and north-facing slopes was quite different at the Preserve. Braun (1917) noted that slopes of the same steepness but of different direction show great differences in the character of the vegetation even though both are on conglomerate rock substrate. The south-facing slope, the driest habitat, was occupied by a maple–oak–elm association. Cobbe (1943) also found the south-facing slope to be less mesophytic and dominated by *A. saccharum*. Braun (1950) noted that the drier slopes and exposed river bluffs of the Illinoian deposits in Kentucky display remnants of an oak–ash–maple forest. The prominence of *Q. muhlenbergii*, the most xeric of the white oak group (Curtis 1959), on the south-facing slope is evidence of the dryness. Mesic shrubs, *Asimina triloba*, *Lindera benzoin*, and

Staphylea trifolia, were abundant on the lower slope and in seepage sites. Braun (1917) noted the occurrence of constantly wet places on conglomerate slopes resulting from a gradual seepage of water from the interior of the rock.

Presently, the disturbed south-facing ridge is occupied by an elm–maple–locust association. The ridge was undergoing advanced succession toward a maple–oak–elm community. The systematic replacement of *Robinia pseudo-acacia* by *Acer* and *Quercus* was readily visible. Many individuals of black locust were dead or dying and that species was not reproducing. Braun (1916) found that black locust did not retain its early importance after other trees were started, and was seldom found within the oak forest. Along with black locust on the top of bluffs in southwestern Ohio were *U. rubra*, *Fraxinus quadrangulata*, and *Q. muhlenbergii* (Braun 1916). *U. rubra* was reproducing to tree replacement size and apparently was maintaining itself as a member of the developing maple–oak–elm community.

The north-facing slope was occupied by a mixed mesophytic association of maple–basswood–beech. Cobbe (1943) found the north slope of Cabin Run ravine to be the most mesophytic community with a dense canopy of *Fagus grandifolia*, *Tilia americana*, *Liriodendron tulipifera*, *Q. alba*, and *Juglans nigra*. Cobbe also recorded *A. saccharum* in the understory along with *F. americana*, *U. rubra*, *Ostrya virginiana*, and *Carpinus caroliniana*. Both *A. saccharum* and *F. americana* were more abundant in the subcanopy than the canopy at the Preserve. Cobbe (1943) stated that a large number of individuals but of small basal area indicated that those trees were not important in the canopy.

The position of *L. tulipifera* in each of the slope associations deserves special mention. Cobbe (1943) found *L. tulipifera* to be most prevalent in the wide protected ravine of Cabin Run, much like its site of abundance at the Preserve, and noted that it reproduced only in openings offered by the death of canopy trees. Overthrow of large canopy trees is a common occurrence on the slopes of the Preserve and possibly is one of the reasons why trees do not reach larger size. The severe slope angles and the sandy nature of the soils will not support large trees. When such trees overturn, *L. tulipifera* from its seed source in the ravine, invades the newly created openings or gaps.

The ridge atop the north-facing slope was occupied by a maple–beech–oak association. Braun (1916) and Cobbe (1943) recorded *F. grandifolia* from the tops of hills, ridges, and knolls, and along with beech on the tops of the hills, are other trees, the most important of which are *A. saccharum*, *Carya laciniosa*, *Q. alba*, and *Q. rubra* (Braun 1916). Such an assemblage is similar to that at the Preserve. The trees were more widely spaced on the ridge than elsewhere in the Preserve and the shrub and subcanopy layers were very sparse. Cobbe (1943) noted that the beech ridge communities were open with no layering. Saplings of *A. saccharum* and *F. grandifolia* reach tree replacement size, but the oaks were not reproducing, especially *Q. alba*. Held and Winstead (1976) also observed poor reproduction by white oak.

The flora of the Preserve is similar to that reported by Cobbe (1943) and Braun (1917) for the glaciated slope areas in southwestern Ohio. I have recorded over 300 species of vascular plants in the Preserve. Conglomerate boulders on the lower slopes are covered with plants. On the drier outcroppings, fewer species are present. The plant successional pattern on those conglomerate cliffs undoubtedly is much like that reported by Braun (1917) on the conglomerate rocks of southern Ohio.

In conclusion, the glaciated portion of Kentucky is limited to a small area in the extreme northern counties, yet those glacial deposits are of significance geologically and vegetationally. The vegetation of the Boone County Cliffs Nature Preserve, on Kansan outwash, differs greatly from the hydromesophytic forests of the Illinoian till plain (Braun 1916, 1936), but compares somewhat to slope and ravine forests on Illinoian till (Cobbe 1943, Held and Winstead 1976).

Braun (1936) reported that where ravines cut through the hydromesophytic flats, a number of species of the mixed mesophytic forest enter, of which tulip poplar and sugar maple are the most important. The ravine and slopes in the Preserve provide numerous microhabitats, and are largely responsible for the similarities observed with the vegetation of dissected Illinoian deposits.

LITERATURE CITED

BEALS, E. W., AND J. B. COPE. 1964. Vegetation and soils in an eastern Indiana woods. Ecology 45:777–792.

BRAUN, E. L. 1916. The physiographic ecology of the Cincinnati region. Ohio Biol. Surv. 2: 115–211.

———. 1917. The vegetation of conglomerate rocks of the Cincinnati region. Plant World 20:380–392.

———. 1936. Forests of the Illinoian till plain of southwestern Ohio. Ecol. Monogr. 6:89–149.

———. 1950. Deciduous forests of eastern North America. The Blakiston Co., Philadelphia, Pa. 596 pp.

CHAPMAN, A. G. 1942. Forests of the Illinoian till plain of southwestern Indiana. Ecology 23:189–198.

COBBE, T. J. 1943. Variations in the Cabin Run Forest, a climax area in southwestern Ohio. Amer. Midl. Nat. 29:89–105.

CURTIS, J. T. 1959. The vegetation of Wisconsin. Univ. Wis. Press, Madison, Wis. 657 pp.

GORDON, R. B. 1936. A preliminary vegetation map of Indiana. Amer. Midl. Nat. 17:866–877.

HELD, M. E., AND J. E. WINSTEAD. 1976. Structure and composition of a climax forest system in Boone County, Kentucky. Trans. Ky. Acad. Sci. 37(3–4):57–67.

KEITH, J. R. 1968. Vegetation of the Pleistocene Drift Region, Northern Kentucky. Trans. Ky. Acad. Sci. 29(1–4):10–20.

KELLER, C. O. 1946. An ecological study of Klein Woods, Jennings County, Indiana. Butler Univ. Bot. Stud. 8:64–81.

MOHLENBROCK, R. W., AND J. W. VOIGT. 1959. A flora of southern Illinois. So. Ill. Univ. Press, Carbondale, Ill. 390 pp.

NELSON, J. C. 1918. Plants from Boone County, Kentucky. Proc. Ind. Acad. Sci. 38:125–143.

RAY, L. L. 1966. Pre-Wisconsin glacial deposits in northern Kentucky. Pp. 195–199. *In* Geological Survey Research 1966. U.S. Geol. Surv. Prof. Pap. 650-D.

———. 1974. Geomorphology and Quaternary Geology of the glaciated Ohio River Valley—a reconnaissance study. U.S. Geol. Surv. Prof. Pap. 826. 77 pp.

SUTTON, G. 1877. Glacial or ice deposits in Boone County, Kentucky, of two distinct and widely distinct periods. Amer. Ass. Adv. Sci. Proc. 25:225–231.

———. 1879. Glacial or ice deposits in Boone County, Kentucky, of two distinct and widely distinct periods. Indiana Geol. Surv. Ann. Rept. 8–9–10:108–113.

WEISENBERGER, B. C., E. W. DOWELL, T. R. LEATHERS, H. B. ODER, AND A. J. RICHARDSON. 1973. Soil survey of Boone, Campbell, and Kenton counties, Kentucky. USDA, Soil Cons. Serv. Gov't. Print. Off. Washington, D.C. 67 pp.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 23–30

Conjugate Addition Reactions of 4-Chlorobenzotriazole, 4,6-Dichlorobenzotriazole, and 4,5,6,7-Tetramethylbenzotriazole

PHILLIP H. MORGAN AND KARL F. HUSSUNG
Department of Chemistry and Geology, Murray State University,
Murray, Kentucky 42071

ABSTRACT

4-Chlorobenzotriazole, 4,6-dichlorobenzotriazole, and previously undescribed 4,5,6,7-tetramethylbenzotriazole were synthesized and subjected to some base-catalyzed conjugate addition reactions. Addition products of 4-chloro- and 4,6-dichlorobenzotriazole with acrylonitrile, acrylamide, crotonic acid and benzalacetophenone were prepared, as well as an addition product of 4,5,6,7-tetramethylbenzotriazole with crotonic acid. Structural assignments were made on the addition products from ultraviolet absorption data; 4-chlorobenzotriazole giving 1- and 2-substituted products, and 4,6-dichloro- and 4,5,6,7-tetramethylbenzotriazole giving only 2-substituted products. Postulations are advanced on the basis of inductive and steric effects in an effort to explain the influence of benzenoid substituents on the course of the addition reaction.

INTRODUCTION

It has been reported previously that azoles with an unsubstituted, exocyclic imino group undergo addition reactions with conjugated, unsaturated systems (Wiley et al. 1954, 1955). Several benzenoid substituted benzotriazoles were later synthesized and addition products prepared and structurally elucidated by ultraviolet absorption data (Wiley, Hussung, and Moffat 1955; Wiley and Hussung 1957). The reported evidence indicated that benzotriazoles with chlorine atoms substituted in both the 4- and 7-positions (4,5,6,7-tetrachlorobenzotriazole and 4,7-dichlorobenzotriazole) add to conjugated systems to give 2-substituted products, whereas 5,6-dichlorobenzotriazole along with the parent, benzotriazole, yielded 1-substituted products. This difference in behavior was attributed to steric hindrance when bulky substituents occupy both the 4- and 7-positions.

In order to obtain a clearer understanding of the effect of benzenoid substituents of benzotriazoles on the course of the addition reaction, 4-chlorobenzotriazole, 4,6-dichlorobenzotriazole, and 4,5,6,7-tetramethylbenzotriazole were prepared and subjected to the base-catalyzed azole addition reaction and the structure of the products elucidated.

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MATERIALS, METHODS, AND RESULTS

The synthesis of 4-chlorobenzotriazole was accomplished by 3 different methods. The first involved the direct chlorination of benzotriazole utilizing the swamping catalyst technique, in which excess aluminum chloride is used as a complexing agent (Gordon and Pearson 1964). An equimolar amount of chlorine was passed into the molten mass of benzotriazole and aluminum chloride to produce 4- and 5-chlorobenzotriazole and some dichlorinated products. A mixture of the monochloro derivatives was separated from the much less soluble dichloro derivatives by fractional recrystallization from water. The mixture melted over a wide range (136–155 C) and gave a neutralization equivalent identical with that of the calculated value (153.5). An attempt to separate the mixture using ethanol and aluminum oxide in a column chromatographic technique failed. Separation of the isomers was accomplished, however, by fractional recrystallization from a 1:2

ethanol–water mixture. The less soluble 4-chlorobenzotriazole was isolated in 9 percent yield.

The second method employed to prepare 4-chlorobenzotriazole involved replacement of the amino group in 4-aminobenzotriazole via the Sandmeyer reaction. Readily available 4-nitrobenzotriazole (Fries et al. 1934) was reduced catalytically and the resulting amino derivative diazotized. Replacement of the diazonium group was effected by addition of a freshly prepared cuprous chloride solution. After completion of the reaction, 4-chlorobenzotriazole was obtained in 4 percent yield.

The third and most satisfactory method of preparation of 4-chlorobenzotriazole was by ring closure that involved diazotization of 3-chloro-o-phenylenediamine formed during catalytic hydrogenation of 6-chloro-2-nitroaniline. The precursor of the diamine was obtained as follows. Sulfonation of o-nitroaniline gave 3-nitro-4-aminobenzenesulfonic acid that was chlorinated, using chlorine gas dissolved in glacial acetic acid, to give 3-nitro-4-amino-5-chlorobenzenesulfonic acid (Wolf et al. 1954) that in turn was desulfonated during steam distillation to give 6-chloro-2-nitroaniline.

4,6-Dichlorobenzotriazole was synthesized as previously described (Wiley and Moffat 1963) by diazotization of 3,5-dichloro-1,2-diaminobenzene, obtained by the stannous chloride and hydrochloric acid reduction of 2-nitro-4,6-dichloroaniline.

Previously undescribed 4,5,6,7-tetramethylbenzotriazole was prepared as follows. Pentamethylbenzene was nitrated below 10 C with a mixture of fuming nitric acid and concentrated sulfuric acid covered with an equal volume of chloroform to give very good yields of dinitroprehnitine (Smith and Harris 1935). The dinitroprehnitine was suspended in glacial acetic acid, palladium on charcoal was added and reduction was effected using a Parr hydrogenator. The resultant tetramethyl-o-phenylenediamine was diazotized in the acetic acid medium with nitrous acid to yield 4,5,6,7-tetramethylbenzotriazole.

The addition products were prepared, in general, by heating the substituted benzotriazole with the conjugated substrate for 15–20 hours in the presence of a base catalyst, either pyridine or benzyltrimethylammonium hydroxide.

Some experimental details for the preparation and characterization of the parent benzotriazoles and their conjugate addition products follow.

4-Chlorobenzotriazole

To 22.9 g (0.133 mole) of 6-chloro-2-nitroaniline dissolved in 300 ml of glacial acetic acid was added 0.5 g of palladium on charcoal catalyst. The mixture was placed on a Parr hydrogenator overnight to reduce the nitroamine to 3-chloro-o-phenylenediamine. The resultant solution was filtered, cooled to 5 C, and an aqueous solution of sodium nitrite was added dropwise with stirring until an excess of nitrous acid was observed. The solution, after being allowed to warm slowly to room temperature, was concentrated to approximately 30 ml and diluted with water to precipitate 12.2 g of the crude product that was 60 percent of the theoretical amount. Decolorization with norite and several recrystallizations from water gave the pure product, mp 169–171 C. The reported melting point is 170 C (Dal Monte and Veggetti 1958).

β-1′-(4′-Chlorobenzotriazolyl)-butyric acid

To a melt of 1.53 g (0.01 mole) of 4-chlorobenzotriazole and 1.30 g (0.014 mole) of crotonic acid (10% water) was added 20 drops of pyridine. The mixture was heated at 100 C for 15 hours, cooled, dissolved in a few milliliters of acetone and poured into 0.5N hydrochloric acid. The resultant solution was decolorized with norite and, upon cooling, a tan oil separated that eventually solidified. After being placed in the refrigerator overnight, some white crystals also precipitated from the solution and were separated mechanically from the tan solid. The crystals weighed 0.55 g which was 23 percent of the theoretical amount. Recrystallization from water gave the pure product, mp 154–155 C.

Analysis: Calculated for $C_{10}H_{10}N_3O_2Cl$: N, 17.53. Found: N, 17.42.

β-2'-(4'-Chlorobenzotriazolyl)-propionitrile

To a mixture of 1.00 g (0.0065 mole) of 4-chlorobenzotriazole and 4.00 g (0.0755 mole) of acrylonitrile was added 10 drops of pyridine. The resulting mixture was heated at 80 C for 20 hours, producing a brown, viscous material on cooling. The oil was dissolved in acetone and brought almost out of solution with hot water. The resultant solution was decolorized with norite and filtered, and the product allowed to recrystallize while cooling overnight in a refrigerator. Filtration produced 0.85 g of white solid that represented a 63 percent yield. Two subsequent recrystallizations from methanol gave the pure sample, mp 131.5–133.5 C.

Analysis: Calculated for $C_9H_7N_4Cl$: N, 27.11. Found: N, 26.94.

β-1'-(4'-Chlorobenzotriazolyl)-propionamide

To a melt of 1.15 g (0.0075 mole) of 4-chlorobenzotriazole and 0.55 g (0.0075 mole) of acrylamide was added 8 drops of benzyltrimethylammonium hydroxide (Triton-B). The solution was heated at 80 C for 20 hours, cooled, and ether was added to precipitate, after stirring, a white solid. The dried solid weighed 1.55 g representing 95 percent of the theoretical amount. Three recrystallizations from acetone gave the pure product, mp 166–168.5 C.

Analysis: Calculated for $C_9H_9N_4OCl$: Cl, 15.78. Found: Cl, 15.57.

β-Phenyl-β-1'-(4'-Chlorobenzotriazolyl)-propriophenone

4-Chlorobenzotriazole (1.53 g, 0.01 mole) and benzalacetophenone (2.08 g, 0.01 mole) were mixed and 4 ml of pyridine added. The mixture was heated at 90 C for 18 hours, cooled, 30 ml of ligroin and 10–20 ml of diethyl ether added, and the resulting mixture stirred until the oil solidified yielding a white solid. The filtered solid weighed 2.80 g for a 77.4 percent yield. One recrystallization from a diethyl ether–ligroin mixture and 1 from an acetone–water mixture gave the analytical sample, mp 139.5–141.5 C.

Analysis: Calculated for $C_{21}H_{16}N_3OCl$: C, 69.71; H, 4.46. Found: C, 69.65; H, 4.37.

β-2'-(4',6'-Dichlorobenzotriazolyl)-propionitrile

A mixture of 2.00 g (0.0106 mole) of 4,6-dichlorobenzotriazole, 6.00 g (0.113 mole) of acrylonitrile, and 5–7 drops of pyridine was heated at 80 C for 18 hours in a test tube fitted with a condensor and immersed in an oil bath heated with a glascol mantle. The reaction mixture was allowed to cool to room temperature and a white solid crystallized. The crystals were filtered, washed with a small amount of cold acrylonitrile, and dried to give 1.16 g of product, representing a 39 percent yield. The product was recrystallized twice from acrylonitrile to yield pure transparent crystals, mp 157–158 C.

Analysis: Calculated for $C_9H_6N_4Cl_2$: Cl, 29.41. Found: Cl, 29.71.

β-2'-(4',6'-Dichlorobenzotriazolyl)-propionamide

To a melt of 1.88 g (0.01 mole) of 4,6-dichlorobenzotriazole and 0.71 g (0.01 mole) of acrylamide was added 5–8 drops of Triton-B. The resulting mixture was heated at 80 C for 20 hours. The reaction mixture was cooled and 10–15 ml of diethyl ether added. After considerable stirring, a white solid formed that was filtered to yield 2.15 g of crude product, representing 83 percent of the theoretical amount. After 1 recrystallization from ethyl acetate and 2 from acetone, 0.20 g of white needles was isolated as an analytical sample, mp 214.5–217 C.

Analysis: Calculated for $C_9H_8N_4OCl_2$: C, 41.72; H, 3.11. Found: C, 41.78; H, 3.06.

β-2'-(4',6'-Dichlorobenzotriazolyl)-butyric acid

To a mixture of 1.88 g (0.01 mole) of 4,6-dichlorobenzotriazole and 1.00 g (0.01

mole) of crotonic acid (10% water) was added enough pyridine to produce a homogeneous solution that was heated at 100 C for 15 hours. Evaporation of the pyridine left an extremely viscous material that was poured into 0.5N hydrochloric acid and stirred to precipitate 1.75 g of crude product for a 64 percent yield. Two recrystallizations from acetone–water gave the analytical sample, mp 134–136 C.

Analysis: Calculated for $C_{10}H_9N_3O_2Cl_2$: N, 15.33; Neutr. equiv., 274.1. Found: N, 15.32; Neutr. equiv., 279.0.

β-Phenyl-β-2′-(4′,6′-Dichlorobenzotriazolyl)-propiophenone

To a melt of 1.88 g (0.01 mole) of 4,6-dichlorobenzotriazole and 2.08 g (0.01 mole) of benzalacetophenone (chalcone) was added 8 drops of Triton-B. The mixture was heated at 80 C for 20 hours. The reaction mixture was cooled, diethyl ether was added and, after stirring, 1.70 g of crude white product precipitated which represented a 43 percent yield. Two recrystallizations from diethyl ether gave 0.55 g of pure product, mp 160–162.5 C.

Analysis: Calculated for $C_{21}H_{15}N_3OCl_2$: C, 63.65; H, 3.82. Found: 63.89; H, 3.86.

4,5,6,7-Tetramethylbenzotriazole

Five g (0.0223 mole) of dinitroprehnitine was dissolved in 150 ml of glacial acetic acid, 0.5 g of palladium on charcoal was added and the solution was placed on the Parr hydrogenator overnight, producing tetramethyl-o-phenylenediamine. The reaction mixture was filtered and 25 ml of water was added. The resulting solution was cooled to 5–10 C and a sodium nitrite solution was added until an excess was observed. During addition of the sodium nitrite solution, a light tan precipitate could be seen forming. The precipitate was filtered, washed with water, dried, and found to weigh 2.50 g representing a yield of 73 percent. The sample was recrystallized from ethanol to give the pure product, mp 291–294 C.

Analysis: Calculated for $C_{10}H_{13}N_3$: C, 68.54; H, 7.48; N, 23.98; Neutr. equiv., 175. Found: C, 68.72; H, 7.39; N, 24.22; Neutr. equiv., 178.

β-2′-(4′,5′,6′,7′-Tetramethylbenzotriazolyl)-butyric acid

To a melt of 1.75 g (0.01 mole) of 4,5,6,7-tetramethylbenzotriazole and 1.00 g (0.01 mole) of crotonic acid (10% water) was added 20 drops of Triton-B. The mixture was heated at 100 C for 20 hours, cooled, and the viscous product was dissolved in 10–15 ml of acetone and poured into 0.5N hydrochloric acid to precipitate 2.00 g of crude product, representing a yield of 76.6 percent of the theoretical amount. The product was dissolved in 1 molar NaOH and filtered into acid in hopes of removing any unreacted 4,5,6,7-tetramethylbenzotriazole as residue on the filter. After several recrystallizations from an acetic acid–water mixture, the pure product was obtained, mp 207–208.5 C.

Analysis: Calculated for $C_{14}H_{19}N_3O_2$: C, 64.35; H, 7.33. Found: C, 64.10; H, 7.27.

Analytical Data

Elemental analyses were conducted by Galbraith Laboratories, Inc., Knoxville, Tennessee. The neutralization equivalent for 4,5,6,7-tetramethylbenzotriazole was obtained by using glacial acetic acid as the solvent, and as titrant, perchloric acid dissolved in glacial acetic acid. All other neutralization equivalents were determined using either water or ethanol–water mixtures to dissolve the sample and standard sodium hydroxide as the titrant. A Beckman Expandomatic pH meter was used in obtaining titration curves for detection of the end points.

Ultraviolet Absorption Spectra

Ultraviolet absorption data on all of the compounds were collected manually from a Beckman DU-2 spectrophotometer, using 10^{-4}–10^{-5} molar solutions of the sample dissolved in spectral grade methanol. The spectra for each of the parent benzotriazoles and their corresponding conjugate addition products are shown in Figs. 1, 2, and 3.

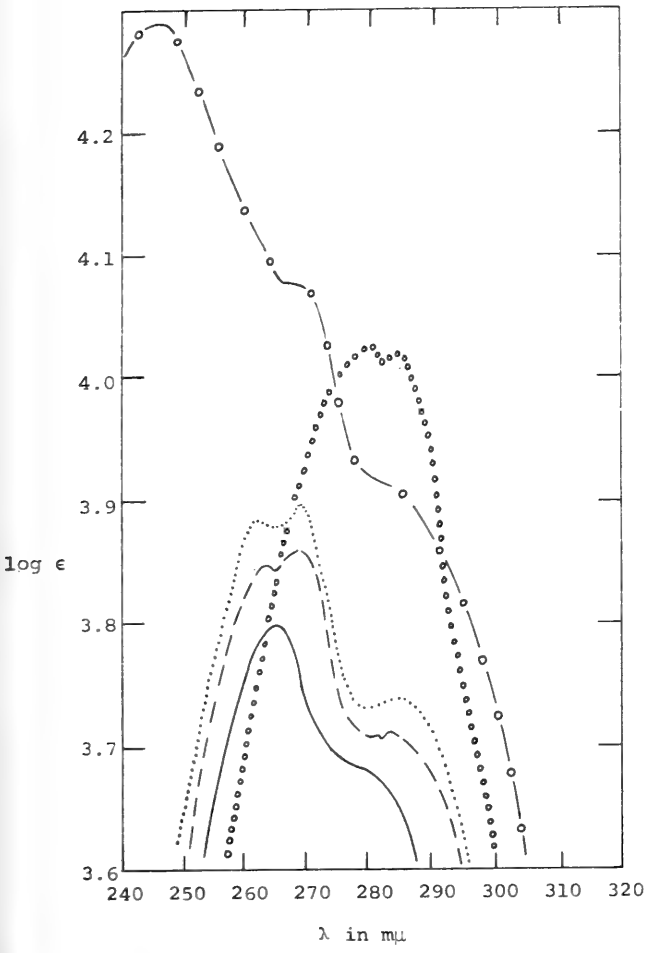

FIG. 1. Ultraviolet absorption spectra for 4-chlorobenzotriazole (———), β-1′-(4′-chlorobenzotriazolyl)-butyric acid (– – – –), β-2′-(4′-chlorobenzotriazolyl)-propionitrile (○ ○ ○), β-1′-(4′-chlorobenzotriazolyl)-propionamide (· · · · · ·), and β-phenyl-β-1′-(4′-chlorobenzotriazolyl)-propiophenone (–○–○–○–).

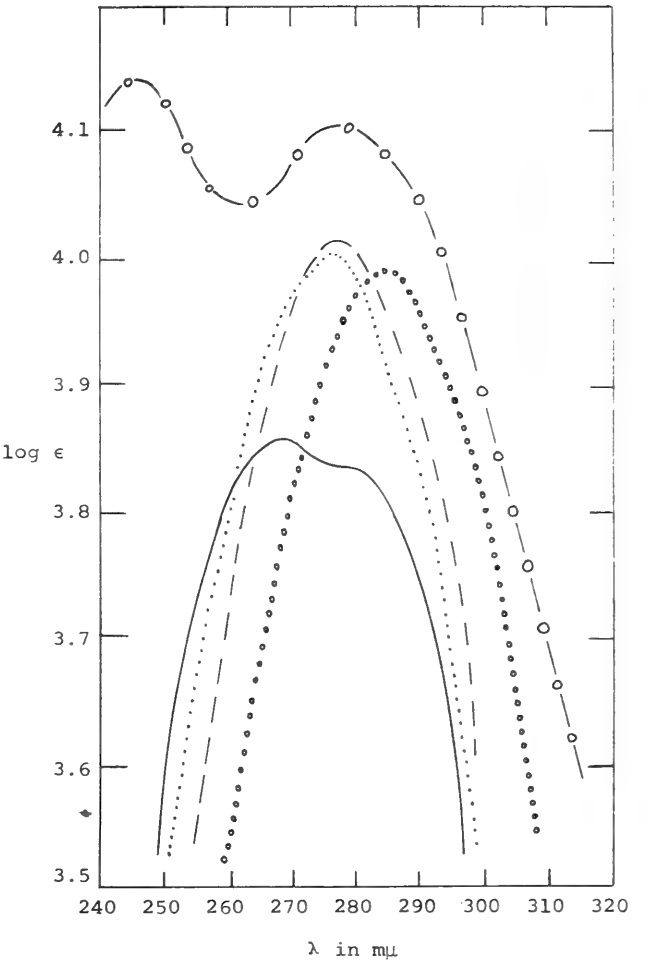

FIG. 2. Ultraviolet spectra for 4,6-dichlorobenzotriazole (———), β-2′-(4′-6′-dichlorobenzotriazolyl)-butyric acid (– – – –), β-2′-(4′,6′-dichlorobenzotriazolyl)-propionitrile (○ ○ ○), β-2′-(4′,6′-dichlorobenzotriazolyl)-propionamide (· · · · · ·), and β-phenyl-β-2′-(4′,6′-dichlorobenzotriazolyl)-propiophenone (–○–○–○–).

DISCUSSION

The ambident, nucleophilic anions of parent benzotriazoles are resonance stabilized. Resonance extremes for the anions of symmetrically substituted 4,7-dichlorobenzotriazole and asymmetrically substituted 4-chlorobenzotriazole are illustrated in Fig. 4.

In the 4,7-dichlorobenzotriazolyl anion, resonance extremes A and C (Fig. 4) are equivalent while in the 4-chlorobenzotriazolyl anion, resonance extremes A, B, and C (Fig. 4) are nonequivalent. As a result, the base-catalyzed azole addition reaction can theoretically give rise to 2 isomeric products with symmetrically substituted benzotriazoles and 3 isomeric products with asymmetrically substituted benzotriazoles (Fig. 5).

The problem of structural isomerism of the 1- and 2-substituted benzotriazoles has been resolved with benzotriazole. Ultraviolet absorption data distinguish between the 2 isomers and chemical data establish the position of the substituents (Krollpfeiffer et al. 1938, Specker and Gawrosch 1942). Further chemical and spectral evidence concerning 1- and 2-substituted benzotriazoles was provided from investigations involving 4,7- and 5,6-dichlorobenzotriazole, 4,5,6,7-tetrachloro- and 4,5,6,7-tetrabromobenzotriazole (Wiley, Hussung, and Moffat 1955; Wiley and Hussung 1957). The spectral

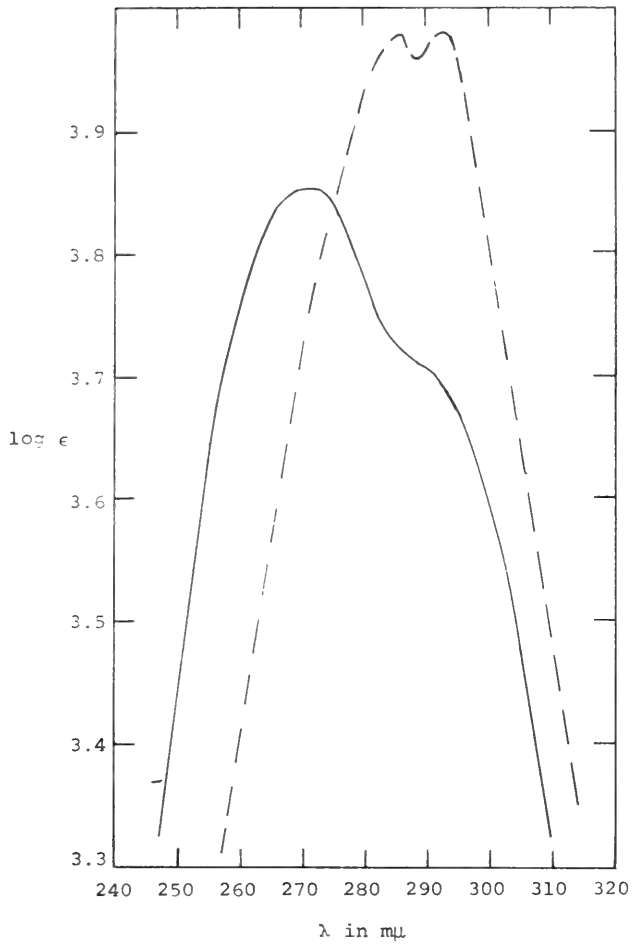

FIG. 3. Ultraviolet absorption spectra for 4,5,6,7-tetramethylbenzotriazole (———) and β-2′-(4′,5′, 6′,7′-tetramethylbenzotriazolyl)-butyric acid (– – –).

evidence indicates that benzotriazoles and their corresponding 1-substituted derivatives show two maxima approximately 20–25 mμ apart. In some spectra, a shoulder before the first maximum is observed. In all spectra, the second maximum is lower in log ε value than the first. Additional spectral evidence indicates that 2-substituted derivatives show 1 principal maximum or a partially resolved double maxima a few millimicrons apart, with higher log ε values than the maxima associated with either the parent benzotriazole or the corresponding 1-substituted derivative.

When 4,6-dichlorobenzotriazole was subjected to the azole addition reaction, adducts were obtained with acrylamide, acrylonitrile, benzalacetophenone, and crotonic acid. All addition products were found by ultraviolet spectroscopy to have the "single" maximum characteristic of 2-substituted benzotriazoles (Fig. 2) and have been assigned structures accordingly. The structure of the addition product with acrylamide is shown in Fig. 5B.

4-Chlorobenzotriazole gave addition products with acrylamide, acrylonitrile, benzalacetophenone, and crotonic acid. From observing the melting point ranges of the crude addition products, the possibility existed that mixtures of isomers were produced, with either the most abundant or least soluble isomer being isolated in the purification procedure. Limited attempts to separate isomers, however, were unsuccessful. Three of the adducts gave ultraviolet spectra characteristic of 1-substituted benzotriazoles while the acrylonitrile adduct gave a spectrum characteristic of 2-substitution (Fig. 1). The 1-substituted products could be either 1,4-disubstituted (Fig. 5A) or 1,7-disubstituted (Fig. 5C) but have been assigned the 1,4 structure. This seems

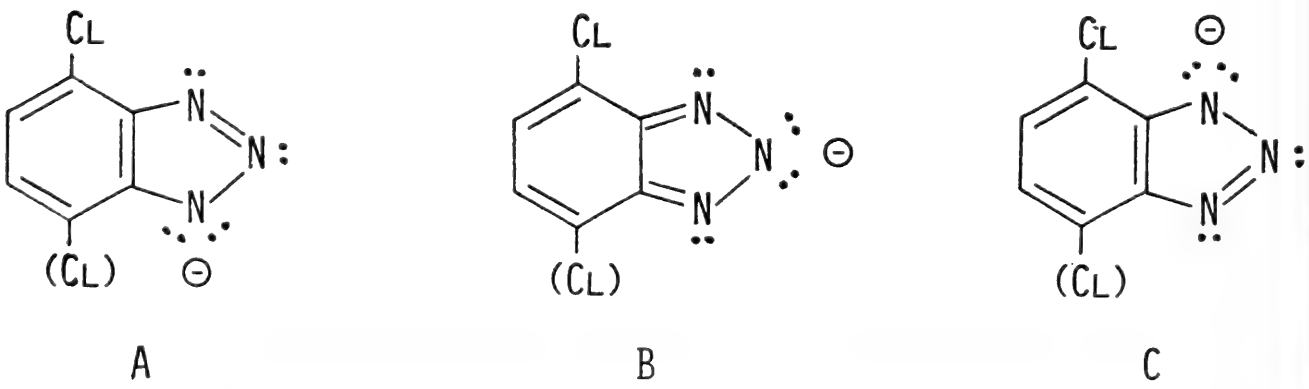

FIG. 4. Resonance extremes for 4-chloro- and 4,7-dichlorobenzotriazolyl anions.

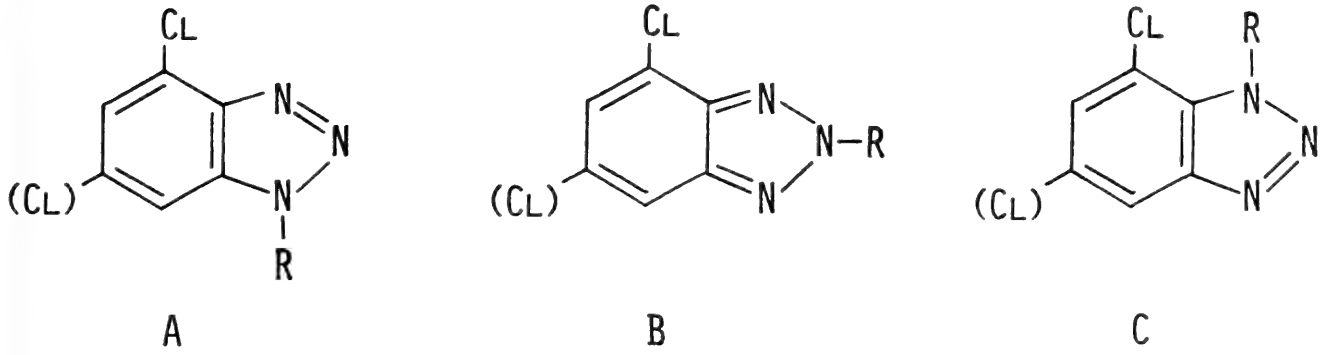

FIG. 5. Theoretically possible addition products of 4-chloro- and 4,6-dichlorobenzotriazole with acrylamide ($R = -CH_2-CH_2-\overset{\overset{O}{\|}}{C}-NH_2$).

justified on the basis of previous work that indicated that symmetrical benzotriazoles with substituents in the 4- and 7-positions gave only 2-substituted and no 1-substituted addition products (Wiley, Hussung, and Moffat 1955; Wiley and Hussung 1957). Therefore, the same effect should be observed in asymmetric benzotriazoles when there is a chlorine substituent on the 4-position only. The nitrogen adjacent to the halogen in the 4-chlorobenzotriazolyl anion should be less nucleophilic, and hence, less favorable as a reaction site in the addition reaction, since the chlorine would reduce the electron density at that nitrogen, inductively, and could, as previously postulated, sterically impair attack at that position.

The slightly acidic nature of benzotriazoles is attributable to resonance stabilization of their anions. Decreased acidity in 4,5,6,7-tetramethylbenzotriazole, due apparently to the electron releasing character of the methyl groups, made attempts at titration with dilute base unsuccessful. This reduced acidity made the preparation of base-catalyzed conjugate addition products difficult. 4,5,6,7-Tetramethylbenzotriazole was added successfully, however, to crotonic acid. The addition product formed was indicated by ultraviolet absorption data to be 2-substituted (Fig. 3).

The best insight into the effect of benzenoid substituents of benzotriazoles on the course of the addition reaction was provided by the studies involving 4,6-dichlorobenzotriazole. Since only 2-substituted products were obtained, the 1-nitrogen adjacent to the ring and not sterically impaired is inactivated by an inductive effect. The fact that both chlorine atoms are positioned meta to that nitrogen produces an electron withdrawing inductive effect of sufficient magnitude to reduce its nucleophilicity, thus rendering it an unfavorable reaction site. If steric hindrance, as previously postulated (Wiley, Hussung, and Moffat 1955; Wiley and Hussung 1957), was the controlling factor, 1-substituted addition products would no doubt have been produced. The fact that 4-chlorobenzotriazole gave both 1- and 2-substituted addition products can be explained on the basis of a smaller inductive effect and the absence of steric interference at the 1-nitrogen.

The presence of electron releasing methyl groups in the 4- and 7-positions should favor inductively, and hinder sterically, the involvement of the 1-(3-) nitrogens in the addition reaction. Since 4,5,6,7-tetramethylbenzotriazole gave a 2-substituted addition product, it appears, on the basis of this evidence, that the steric factor plays the dominant role.

LITERATURE CITED

DAL MONTE, D., AND P. VEGGETTI. 1958. Triazoles and benzotriazoles. Boll. Sci. Fac. Chim. Ind. Univ. Bologna 16:1–9.

FRIES, K., H. GUTERBOCK, AND H. KUHN. 1934. Bicyclic compounds and their comparison with naphthalene. IV. Series of azimidobenzenes and N-methylazimidobenzenes. Ann. Chemie 511:213.

GORDON, M., AND D. E. PEARSON. 1964. The swamping catalyst effect. VI. The halogenation of isoquinoline and quinoline. J. Org. Chem. 29:329.

KROLLPFEIFFER, F., H. POTZ, AND A. ROSENBERG. 1938. N-Alkylbenzotriazoles and the constitution of benzotriazole. Berichte 71B:596.

SMITH, L. I., AND S. A. HARRIS. 1935. Studies on the polymethylbenzenes. XI. The nitration of pentamethylbenzene and of hexamethyl- and hexaethylbenzene. J. Amer. Chem. Soc. 57:1289.

SPECKER, H., AND H. GAWROSCH. 1942. Ultraviolet absorption of benzotriazoles, pyridones and their salts. Berichte 75B:1338.

WILEY, R. H., AND K. F. HUSSUNG. 1957. Halogenated benzotriazoles. J. Amer. Chem. Soc. 79:4395.

———, ———, AND J. MOFFAT. 1955. Preparation, structure, and properties of 4,5,6,7-tetrachlorobenzotriazole and its 1- and 2-substituted products. J. Amer. Chem. Soc. 77: 5105.

———, AND J. MOFFAT. 1963. 4,6-Dichlorobenzotriazole. J. Chem. Eng. Data 8(2):279.

———, N. R. SMITH, D. M. JOHNSON, AND J. MOFFAT. 1954. Conjugate addition reactions of azoles: 1,2,3-triazole and benzotriazole. J. Amer. Chem. Soc. 76:4933.

———, ———, ———, AND ———. 1955. Conjugate addition reactions of azoles. II. 1,2,4-Triazole, tetrazole, nitropyrazoles and benzotriazole. J. Amer. Chem. Soc. 77:2572.

WOLF, F. J., K. PFISTER, III, R. M. WILSON, JR., AND C. A. ROBINSON. 1954. Benzotriazines. I. A new series of compounds having antimalarial activity. J. Amer. Chem. Soc. 76: 3551.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 31–38

Some Hydrologic Characteristics of a Small Forested Watershed in Eastern Kentucky

EVERETT P. SPRINGER AND GEORGE B. COLTHARP
Department of Forestry, University of Kentucky,
Lexington, Kentucky 40506

ABSTRACT

Evaluation of land use–water yield relationships requires knowledge of baseline or background hydrologic characteristics of relatively undisturbed watersheds. Hydrologic data were collected in 1972–1976 on a 93.70-ha undisturbed forested watershed in the Eastern Mountain and Coalfield region of Kentucky. During that period, precipitation averaged 136.07 cm annually. Total water yield (runoff) averaged 80.20 cm or 59 percent of the average annual precipitation. Mean annual stormflow (quickflow) volume comprised 44 percent of the mean annual runoff. Steeply sloping flow duration curves coupled with a high percentage of the total annual runoff that occurred as stormflow characterizes the watershed as having "flashy" hydrologic response.

INTRODUCTION

In recent years, increased attention has been devoted to the quantity and quality of surface water that drains from forested watersheds. The Eastern Mountain and Coalfield Region is mainly forested, and contains the primary watersheds for more than half of Kentucky. The Kentucky, Licking, Big Sandy, and Cumberland rivers, that originate in the region, provide water for industrial and public use for the eastern half of the state. Several recent reports (Kentucky Department of Commerce 1975, Krieger et al. 1969) show that approximately 96 percent of the water used in the Eastern Mountain and Coalfield Region and 79 percent of the water used in the Bluegrass Region is in the form of surface water. With this demonstrated dependency upon surface water supplies, land use practices in the headwater areas can greatly affect the quantity and quality of flow of that vital resource.

In order to evaluate the current status of land use–water yield relationships, we need to know the baseline or background values of water quantity and quality produced from relatively undisturbed forested watersheds. Such values are essential yardsticks in any evaluation of environmental degradation.

Forest hydrology studies currently underway at the University of Kentucky Robinson Forest in eastern Kentucky are providing some of these much needed baseline data. Several small forested watersheds have been monitored since 1971, and this paper summarizes some of the pertinent hydrologic characteristics of one of those areas.

METHODS AND MATERIALS

Study Area

Robinson Forest lies 40.23 km south of Jackson, Kentucky, in the Eastern Mountain and Coalfield Physiographic Province. The University of Kentucky acquired the 6,075-ha tract in 1923 following logging of the virgin stands; there has been no extensive logging since acquisition. The bedrock is comprised of alternating layers of sandstones, siltstones, shales, and coal from the Pennsylvanian Age (Hutchins et al. 1976). Some layers of the bedrock are more resistant to weathering than others, therefore, the resulting slopes are dissected by benches. The deepest soils occur along the upslope sides of benches and in cove sites, while rock outcrops are common along slopes and the outslope edges of benches. From a hydrologic viewpoint, those soils are classified as shallow. The Shelocta and Rigley series, found on slopes, comprise over 75 percent of the soils of Robinson

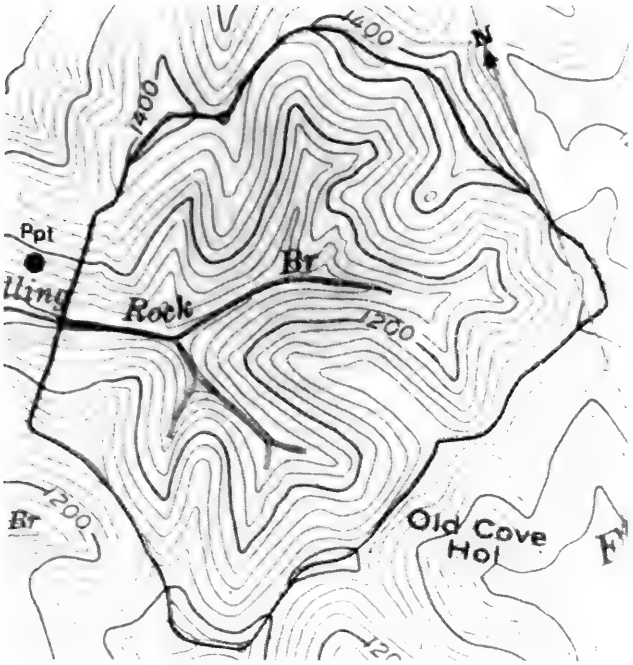

FIG. 1. Topographic map of Falling Rock Watershed.

Forest (Hutchins et al. 1976). The Gilpin and Steinsburg series are residual soils on ridgetops, and the Pope series has evolved from alluvial material along the bottoms (Graves et al. 1977).

Falling Rock Watershed is a 93.7-ha tract selected as the control watershed for future studies (Fig. 1). Its orientation is predominantly northwest, and the slopes average 44 percent. The main channel length is 670 m and slopes at a rate of 54.6 m/km. The basin is oval and the long axis runs from southwest to northeast. The 100 percent forest cover on the watershed has an average basal area of 20.40 m^2/ha, with the predominant species being oaks (*Quercus* spp.), yellow poplar (*Liriodendron tulipifera*), hickories (*Carya* spp.), and maples (*Acer* spp.). Carpenter and Rumsey (1976) published a complete checklist of species on Robinson Forest.

Measurements

Total incoming precipitation was measured with a weighing type gauge in a small clearing near the stream gauging station (Fig. 1).

Streamflow was measured continuously by a 3:1 side-sloped, broad-crested triangular weir equipped with an FW-1 water level recorder (Fig. 2). The weir cutoff wall is tied into shale on each side and across the bottom. The weir has a rated head capacity of 0.9 m, equivalent to 4,825.7 l/sec.

Data Reduction

Precipitation charts were point picked by hand, and the data transferred to computer cards. Reduction of the data to 2, 5, 10, 15, and 30-min and 1, 2, 6, and 24-hour intensities, for each event and daily and monthly totals, was accomplished by means of a previously developed computer program (Shanholtz and Burford 1967).

Streamflow charts were reduced by means of an Oscar-K chartreader available through the U.S. Forest Service, Berea, Kentucky. The Oscar-K utilizes an X–Y coordinate system, with time on the X axis and stage on the Y axis; the chartreader is interfaced with a keypunch so that values are punched directly into cards. The cards were processed into streamflow information using the Coweeta streamflow program described by Hibbert and Cunningham (1967). The output of the program includes (1) mean daily flow in lsm (liters per second per square mile), with monthly and annual summaries; (2) flow frequency by minutes; (3) stormflow information; and (4) stormflow summary by months, seasons, and years.

RESULTS AND DISCUSSION

Precipitation

The precipitation pattern is typical for this area of the United States; low intensity, long duration rainstorms predominate during winter, and high intensity, convectional storms occur in summer. Snow is an insignificant form of precipitation and no attempt has been made to determine its relative contribution (percentage of total). Mean annual precipitation for 1972–1976 was 136.07 cm; the driest year was 1976 when 117.85 cm fell and the wettest was 1974 when 156.99 cm fell. The amounts and distribution of the monthly and annual pre-

FIG. 2. V-notch weir used for measurement of streamflow.

cipitation for the study period (Table 1) indicate that March receives the highest mean monthly precipitation of 17.19 cm and August is the lowest, receiving 6.80 cm.

Streamflow

Monthly and annual streamflow for 1972–1976 are shown in Table 2. Mean annual streamflow was 80.20 cm, 59 percent of the

TABLE 1.—MONTHLY, ANNUAL, AND MEAN PRECIPITATION (CM), FALLING ROCK WATERSHED, 1972–1976

Month	Year					
	1972	1973	1974	1975	1976	$\bar{x}$
Jan	20.70	4.11	22.23	9.17	9.32	13.13
Feb	18.08	7.32	4.83	9.09	8.64	9.59
Mar	10.29	13.46	17.86	28.02	16.33	17.19
Apr	21.64	12.95	11.99	9.25	1.07	11.38
May	7.70	14.66	14.61	17.65	6.83	12.29
Jun	7.75	5.44	24.89	9.25	16.51	12.77
Jul	8.89	15.57	7.24	4.14	12.34	9.64
Aug	0.89	3.76	13.72	7.87	7.75	6.80
Sep	11.43	5.59	9.78	17.02	13.46	11.46
Oct	7.62	9.14	4.95	12.01	15.19	9.78
Nov	10.46	17.58	11.43	10.13	2.79	10.48
Dec	17.02	10.80	13.46	9.07	7.62	11.59
Annual	142.47	120.38	156.99	142.67	117.85	136.07

TABLE 2.—MONTHLY, ANNUAL, AND MEAN STREAMFLOW (CM), FALLING ROCK WATERSHED, 1972–1976

Month	Year					
	1972	1973	1974	1975	1976	$\bar{x}$
Jan	19.99	1.98	22.81	13.18	3.91	12.37
Feb	19.46	8.92	4.42	11.71	10.67	11.04
Mar	9.02	7.67	15.75	31.57	13.49	15.50
Apr	28.09	9.65	10.82	10.57	3.10	12.47
May	3.71	7.75	3.40	10.41	0.86	5.23
Jun	0.53	0.64	12.50	2.46	3.12	3.85
Jul	0.46	0.71	0.81	0.23	1.47	0.74
Aug	0.15	0.38	0.91	0.15	1.65	0.65
Sep	0.56	0.18	2.59	0.74	1.14	1.04
Oct	0.66	0.41	1.73	1.96	9.88	2.93
Nov	2.77	7.37	6.88	5.11	2.24	4.87
Dec	17.68	6.30	10.24	6.35	7.11	9.54
Annual	103.08	51.96	92.86	94.44	58.64	80.20

average annual precipitation, an exceptionally high value! The highest annual yield was in 1972 with 103.08 cm and the lowest yield was the following year with 51.96 cm.

The mean monthly data in Fig. 3 indicate the temporal distribution of the mean annual flow. On the average, the first 4 months of the year accounted for 64 percent of the annual runoff. If May and June are included, those 6 months produced 75 percent of the annual runoff. That period corresponds with the dormant vegetational

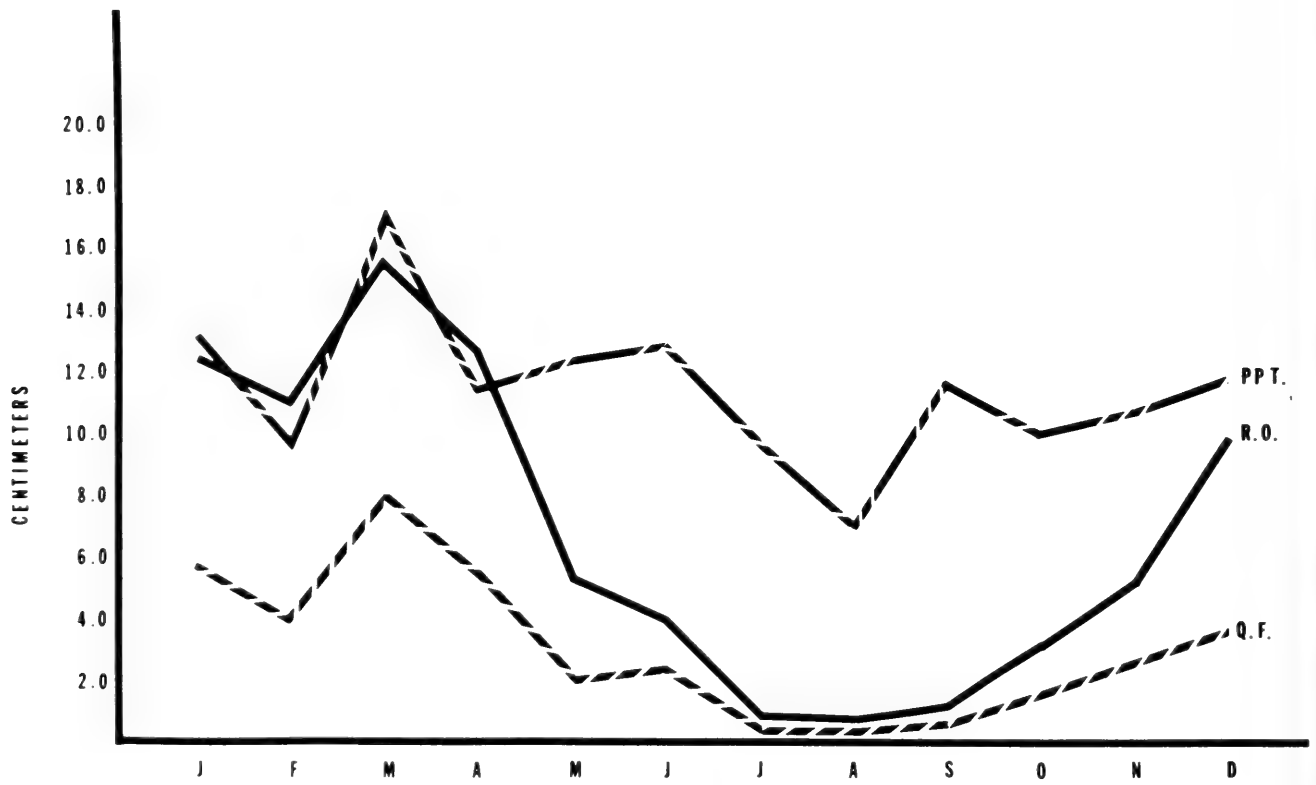

FIG. 3. Relationship between mean monthly precipitation, runoff, and quickflow for Falling Rock Watershed, 1972–1976.

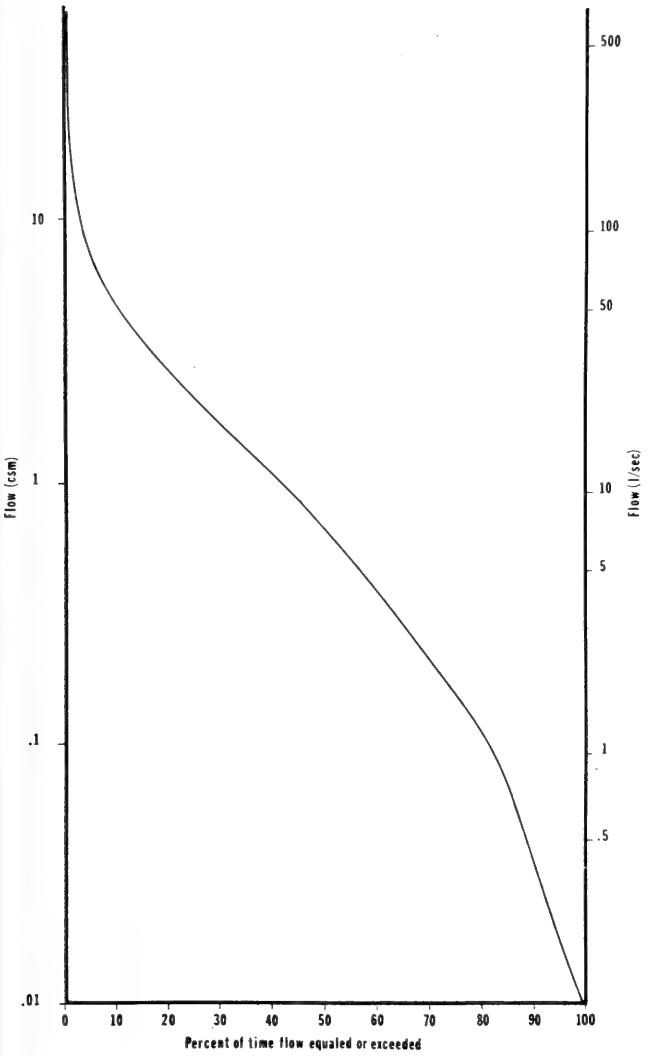

FIG. 4. Composite flow duration relationship for Falling Rock Watershed, 1972–1976.

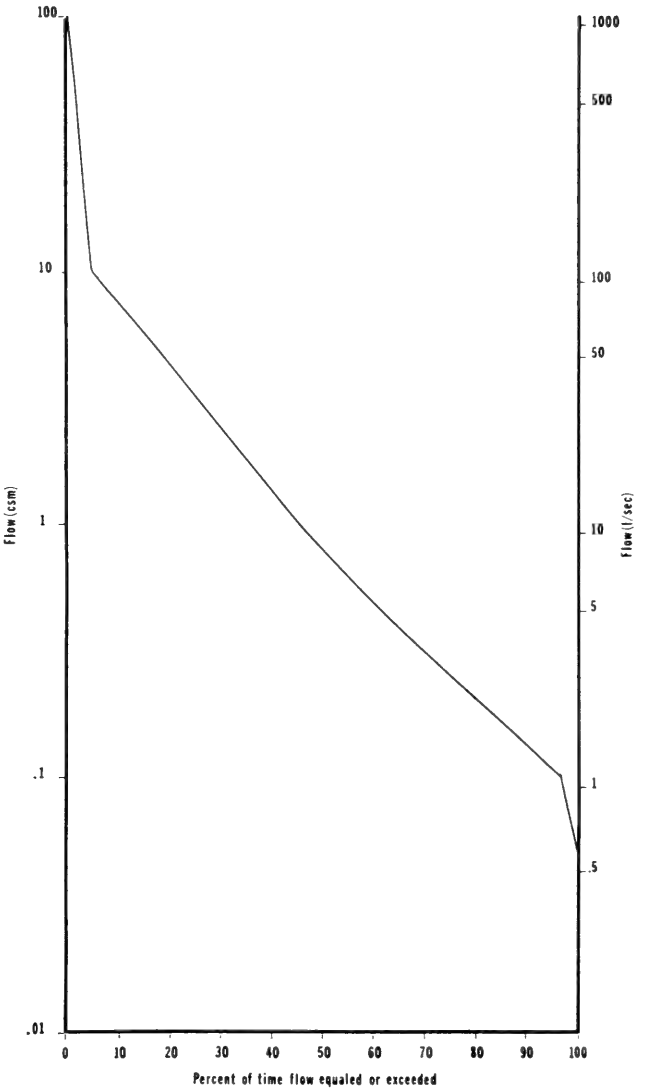

FIG. 5. Flow duration relationship for wet year 1974.

season and is characterized by full soil moisture recharge. Reinhart et al. (1963) found a similar relationship at the Fernow Experimental Forest in West Virginia. The relatively shallow soils do not have a large water storage capacity, and recharge occurs quickly. Such a lack of a large soil water storage reservoir produces "flashy" runoff conditions on those watersheds, and little or no storage dictates that baseflow cannot be sustained during prolonged dry periods, and the streams do not flow for brief periods during the year. Low flows occur primarily in July and August, periods of low precipitation and high evapotranspiration demand. For 11 days in late August and early September 1975 there was no streamflow.

Flow Duration

Flow duration curves (Figs. 4–6) are presented to indicate the distribution of flows and further substantiate the "flashy" characterization of the watershed. Fig. 4 represents the total 1972–1976 period when mean discharge was 7.00 l/sec. Fig. 5 represents 1974, characterized as a wet year, and it is obvious from the curve that flow was not less than 0.60 l/sec for any significant percentage of time during the year. Also, mean flow for that year was 8.20 l/sec, considerably above the composite mean of 7.00 l/sec. Fig. 6 represents 1976, a dry year when mean discharge was 5.20 l/sec, and during that year discharge exceeded 10.20

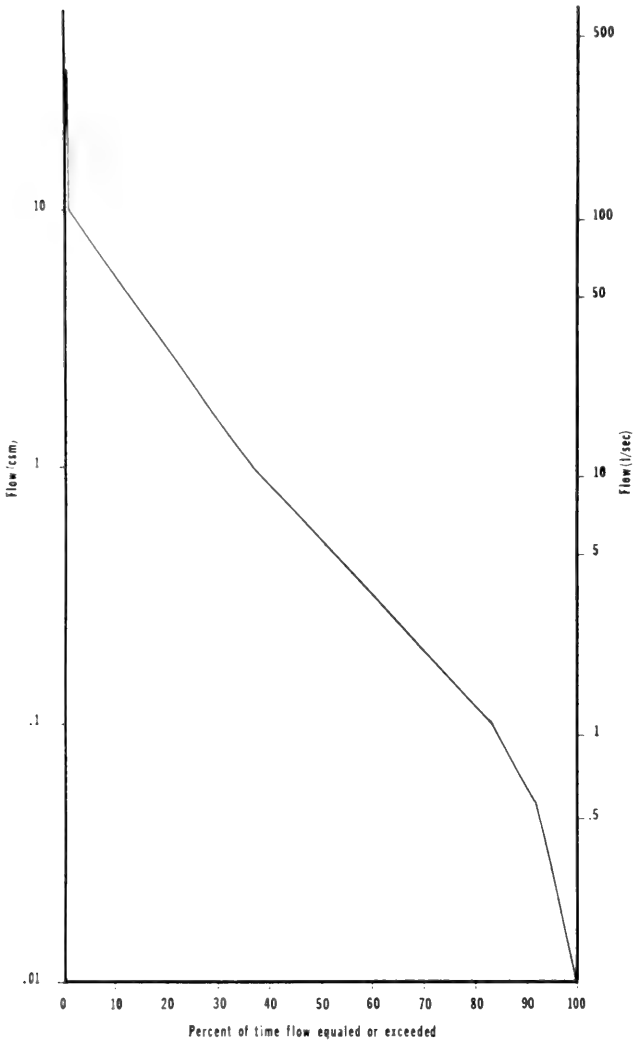

FIG. 6. Flow duration relationship for dry year 1976.

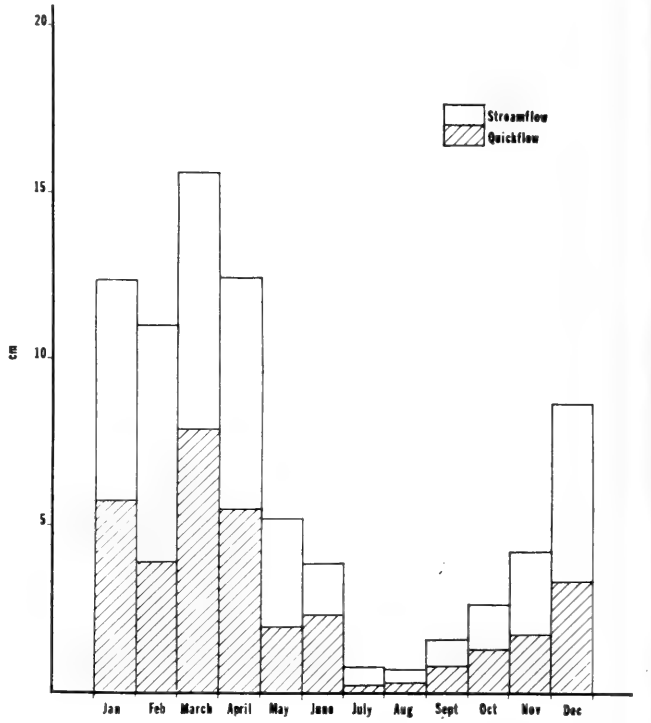

FIG. 7. Relationship between mean monthly streamflow and quickflow for Falling Rock Watershed, 1972–1976.

l/sec only 36 percent of the time, while the average for that interval was 43 percent.

Morisawa (1968) indicated that flow duration curves allow characterization of runoff from watersheds. Those watersheds with large storage capacity will exhibit flat flow duration curves, whereas watersheds with little or no storage have steeply sloped curves. The curves from Falling Rock Watershed have steep slopes, further evidence of lack of moisture storage within the soils of Robinson Forest.

Stormflows

Stormflow or direct runoff from forested watersheds consists almost entirely of subsurface flow, while overland flow or surface runoff is virtually nonexistent. Hewlett and Hibbert (1967), recognizing the processes that operate in forested watersheds, classified storm hydrograph volumes as quickflow and delayed flow. Quickflow is distinguished from delayed flow by a line with a slope of 0.55 l/sec/km^2/hr projected from the rising limb to falling limb of the hydrograph. That method was used to analyze hydrographs from Falling Rock Watershed. The resultant monthly and annual quickflow volumes are presented in Table 3. The largest quickflow volumes usually occur during months of soil moisture recharge and little or no evapotranspiration. However, June 1974 had an abnormally high value of 8.97 cm that resulted from above average precipitation during March–June 1974. In Fig. 7, that presents monthly mean streamflow and quickflow for the study period, July is the only month where quickflow was less than 30 percent of the mean monthly flow. During the study, quickflow averaged 44 percent of the mean annual runoff. Hewlett and Hibbert (1967), surveying forested watersheds in the eastern and southeastern United States, found only 1

TABLE 3.—MONTHLY, ANNUAL, AND MEAN QUICKFLOW VOLUMES (CM), FALLING ROCK WATERSHED, 1972–1976

Month	Year					
	1972	1973	1974	1975	1976	$\bar{x}$
Jan	10.54	0.01	12.95	3.78	1.47	5.75
Feb	10.15	1.64	0.10	3.37	4.07	3.87
Mar	2.65	2.53	5.95	20.12	8.06	7.86
Apr	16.80	3.98	2.90	3.78	0.05	5.50
May	0.35	3.72	0.76	4.75	0.05	1.93
Jun	0.04	0.06	8.97	0.84	1.61	2.30
Jul	0.07	0.22	0.11	0.01	0.46	0.17
Aug	0	0.03	0.21	0.02	0.82	0.22
Sep	0.40	0.02	0.84	0.24	0.65	0.43
Oct	0.04	0.08	0.37	0.94	5.92	1.47
Nov	0.77	5.53	2.19	3.17	0	2.33
Dec	8.60	3.30	2.56	1.70	2.08	3.65
Annual	50.41	21.12	37.91	42.72	25.24	35.48

forested watershed with a quickflow response as high as Falling Rock Watershed. That watershed, at Union, South Carolina, has an 85 percent forest cover.

There have not been enough years of data collection to determine any return periods on peakflows. The data presented in Table 4 represent the highest yearly peaks obtained during this study. It should be noticed that 1973, categorized as a dry year, had the lowest peak value.

SUMMARY

Precipitation and streamflow data were collected over a 5-year period on a small undisturbed forested watershed in the Eastern Mountain and Coalfield Region of Kentucky. Hydrologic characteristics were determined from the data pool. Such baseline hydrologic information is lacking for the region. Precipitation averaged 136.07 cm for the period. Total streamflow and quickflow volumes were closely related, with most of the annual volume produced during the dormant season. Mean annual streamflow of 80.20 cm represented 59 percent of the mean annual precipitation, and quickflow accounted for 44 percent of the total runoff. Quickflow volumes coupled with steeply sloping flow duration curves categorize the watershed as flashy, from a hydrologic viewpoint.

The potential of the region as a lumber and energy producer is enormous, but it is important that those resources be obtained without destroying watershed values. To better understand such watersheds, experiments must be conducted to evaluate treatment effects on the water resource at Robinson Forest.

TABLE 4.—YEARLY MAXIMUM RATE OF FLOW (L/SEC), FALLING ROCK WATERSHED, 1972–1976

Date	Flow rate
12 Apr 1972	3,375
26 Nov 1973	1,195
22 Jun 1974	3,060
25 Apr 1975	1,818
21 Mar 1976	2,999

LITERATURE CITED

CARPENTER, S. B., AND R. L. RUMSEY. 1976. Trees and shrubs of Robinson Forest, Breathitt County, Kentucky. Castanea 41:277–282.

GRAVES, D. H., G. B. COLTHARP, M. C. HAMMETTER, D. C. JORDAN, C. L. SHILLING, AND R. F. WITTWER. 1977. Remote sensing of effects of land use practices on water quality. Final Report Contract No. NAS8-31006. 159 pp.

HEWLETT, J. D., AND A. R. HIBBERT. 1967. Factors affecting the response of small watersheds to precipitation in humid areas. Pp. 275–290. *In* W. E. Sopper and H. W. Lull (Eds.). International Symposium on Forest Hydrology. Pergamon Press, New York, N.Y. 813 pp.

HIBBERT, A. R., AND G. B. CUNNINGHAM. 1967. Streamflow data processing opportunities and application. Pp. 725–736. *In* W. E. Sopper and H. W. Lull (Eds.). International Symposium on Forest Hydrology. Pergamon Press, New York, N.Y. 813 pp.

HUTCHINS, R. B., R. L. BLEVINS, J. D. HILL, AND E. H. WHITE. 1976. The influence of soils and microclimate on vegetation of forested slopes in eastern Kentucky. Soil Science 121 (4):234–241.

KENTUCKY DEPARTMENT OF COMMERCE. 1975. Natural resources of Kentucky. Frankfort, Ky. 42 pp.

KRIEGER, R. A., R. V. CUSHMAN, AND N. D. THOMAS. 1969. Water in Kentucky. Ky. Geol. Surv., Lexington, Ky. 51 pp.

MORISAWA, M. 1968. Streams, their dynamics and morphology. McGraw-Hill Book Co., New York, N.Y. 175 pp.

REINHART, K. G., A. R. ESCHNER, AND G. R. TRIMBLE. 1963. Effect on streamflow of four forest practices in the mountains of West Virginia. USDA For. Serv. Res. Pap. NE-1. 79 pp. Northeast For. Exp. Sta., Upper Darby, Pa.

SHANHOLTZ, V. O., AND J. B. BURFORD. 1967. Computer systems for reduction and analysis of hydrologic data. USDA Agric. Res. Ser. ARS-41-132. 90 pp.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 39–53

The Louisville Meteorite—Fall and Recovery

GRAHAM HUNT
Department of Geology, University of Louisville, Louisville, Kentucky 40208

AND

THOMAS E. BOONE
Rauch Planetarium, University of Louisville, Louisville, Kentucky 40208

ABSTRACT

The Louisville Meteorite entered the earth's atmosphere at 1530 EST, 31 January 1977 as a bolide that created a flash visible for 160 km. Sightings checked by a Brunton compass assisted in working out a possible sequence of 4 major fragmentation and/or illumination events. During those events, the fireball traveled on an azimuth of S 87 W, and counterclockwise to the earth's revolutionary path. To date, 4 stones found within an ellipse of fall in central and western Louisville, Kentucky, have been identified as fragments of a chondritic meteorite. The ellipse is about 10 km long and 7 km wide with a long axis S 87 W, the largest stone near its southwestern apex. In falling, 4 stones struck 2 rooftops, a car top, and the window of a house. Mapping and recovery to date has yielded 1,312 g of chondritic meteorite material. The largest stone weighed 1,051 g.

Microscopic investigation and chemical studies have established that the Louisville Meteorite is an ordinary chondrite with shock metamorphic banding, an olivine–hypersthene chondrite (L6 in the classification of Van Schmus and Wood 1967).

INTRODUCTION

From early geologic times, our earth and the other members of the solar system have been bombarded by solid bodies from space called meteorites. They may be the oldest and most primitive pieces of planetary matter that we have access to at the present time, approximately one billion years older than the oldest known earth rocks.

It is important to distinguish between "finds" and "falls" in meteorite studies. Among the meteorite falls that have been observed and recovered, about 92 percent are stones, 6 percent irons, and 2 percent stony irons. Those meteorites found but not observed to fall are 35 percent stones, 59 percent irons, and 6 percent stony irons (Prior 1953).

Meteorites usually are named after geographic landmarks such as the nearest city or village large enough to have a post office. J. Lawrence Smith (1877) drew attention to the remarkable fact that during about 18 years in the late 1800s there had been 12 falls of meteorites in the United States, 8 of which had occurred over the prairie regions of the west, not far from his home in Louisville. In Kentucky, 24 meteorites have been positively identified (Mason 1962), and 5 of them are classified as falls: Bath Furnace, Cumberland Falls, Cynthiana, Murray, and the latest addition to the list, Louisville (Hunt 1977).

ACKNOWLEDGMENTS

Television stations WLKY (Fran Severn), WHAS (Chuck Olmstead), and WAVE (Norm Lewis), and newspapers (The Louisville Times, The Courier-Journal, and the New Albany Tribune) gave the Louisville meteorite excellent "front page" coverage. Staff members Mark Webb and Martha Hays of the Rauch Planetarium aided greatly in gathering data. Barry Williams, Darren Doderer, and Danny Cain, geology students, University of Louisville, assisted in ground searches. The Hunt family, Dalyce, Freya, Shel, and Rod, participated

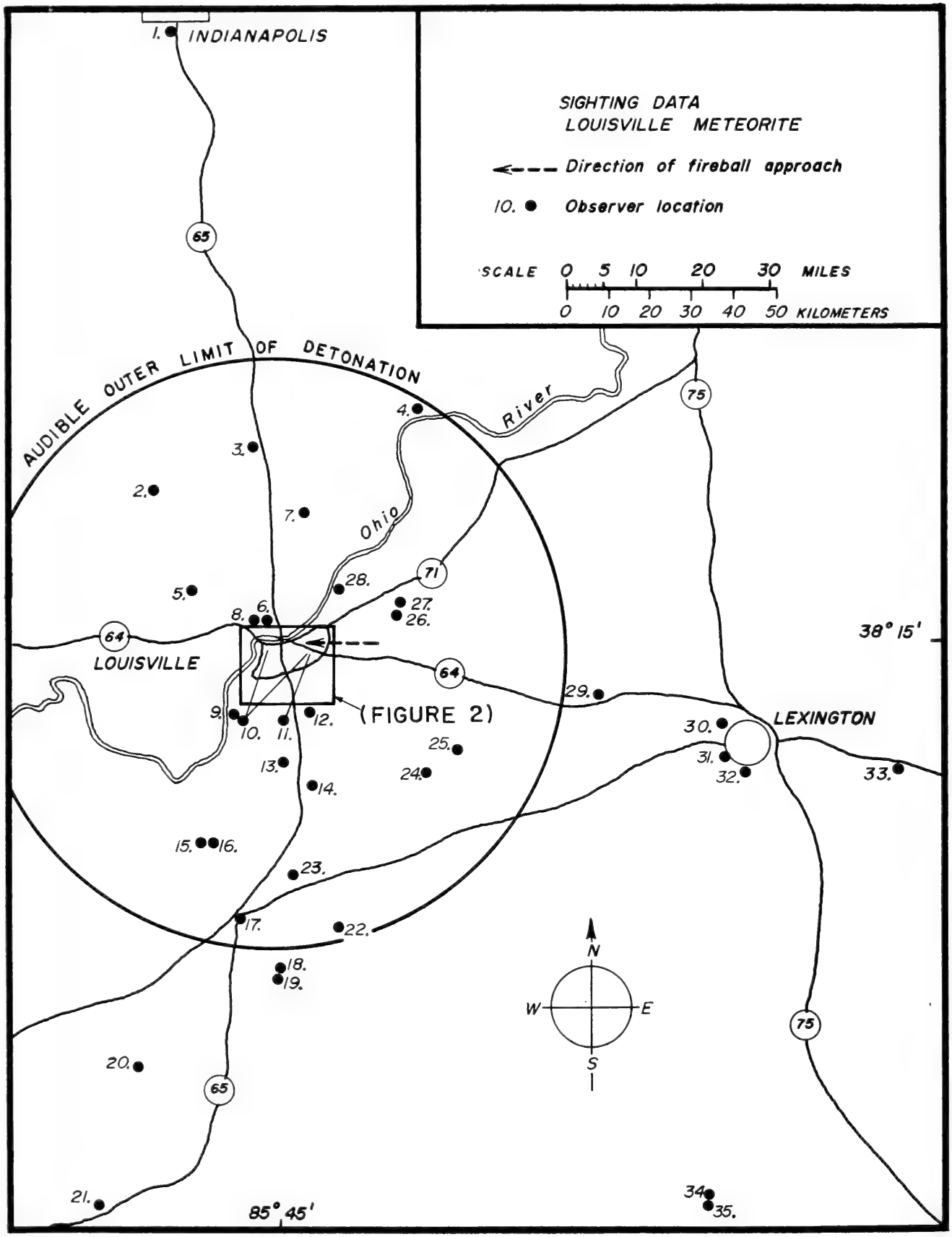

FIG. 1. Sighting data of the Louisville Meteorite showing the direction of approach of the fireball, the location of observers, and the outer limits of audible detonation.

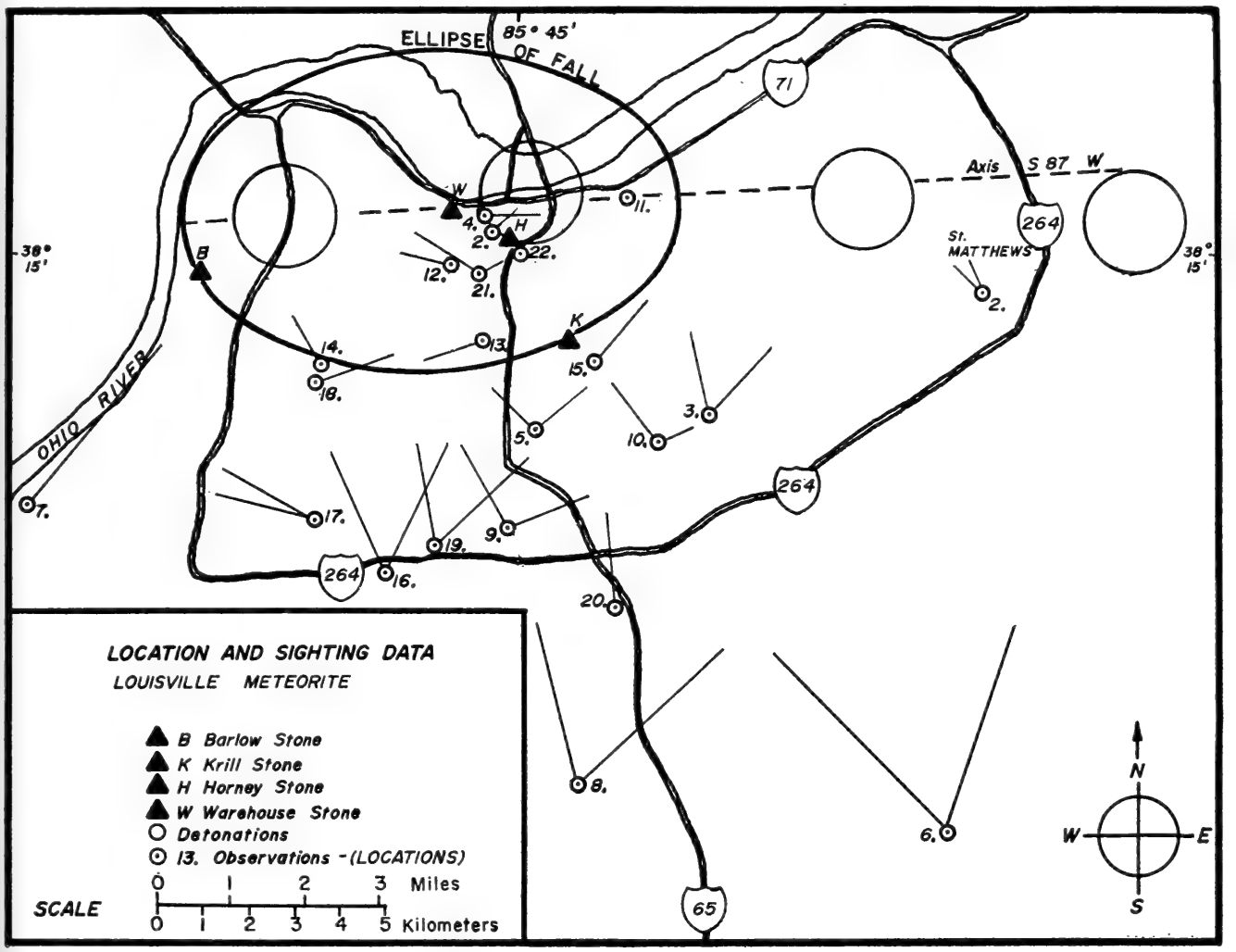

FIG. 2. Sighting data of the Louisville Meteorite showing the ellipse of fall, the flight axis, observer locations, and points of recovery of the 4 stones.

in the ground search and the collection of sighting data. Louisvillians and citizens of the surrounding areas were very helpful in supplying sighting data. Mr. and Mrs. R. J. Barlow, Mrs. Krill, Mrs. Horney, and Mr. R. L. White generously made available their specimens for research purposes. Research on the meteorite was supported by the University of Louisville. E. Jarosewich provided the bulk analysis.

We gratefully acknowledge the help of J. Kalliokoski and the use of the facilities of Michigan Technological University. R. E. Folinsbee reviewed the manuscript.

THE METEORITE

Fall

The Louisville meteorite entered the earth's atmosphere over metropolitan Louisville, Kentucky, at 2030 GMT (1530 EST) on 31 January 1977. The senior author investigated 165 reported observations of the detonating bolide, and during the week following the fall, identified 4 widely separated individual chondrites (Hunt 1977).

Various types of sighting data, as outlined on standard fireball cards, were obtained from reliable observers during the spring following the fall. Those data include: azimuths for first seen and end point, angle to horizon, estimated velocity, number and character of detonations, direction of fireball trajectory, the form and colors of the fireball, the length of time of observation, and the exact location of the observer.

Locations of the observers are shown in Figs. 1 and 2, and their eye witness accounts are summarized in Tables 1 and 2. The bearings to the observers first sighting and

TABLE 1.—INFORMATION GATHERED IN INDIANA AND KENTUCKY ON THE SIGHTING OF THE FIREBALL OF THE LOUISVILLE METEORITE. OBSERVER LOCATIONS ARE FOR FIG. 1

	Observer location	Sound	Direction of flight	Comments on meteorite
			INDIANA	
1	Farm Credit Bank, Indianapolis	Nil	ENE to WSW	Silvery white with multiple fragmentation
2	Salem, Highway 60	Nil	N to S	Gold sparkle tinted red, 4–5 sec observation, 1515 hours
3	I-65, ca. 30 miles N of Louisville	Nil	E to W	Burned out before it hit ground, like flame thrower or Roman candle
4	Madison			White to blue form with pink tail
5	Floyds Knobs	Sizzling	NW falling	Intensely bright orange, burned out leaving curved trail, few seconds
6	1718 Marlow Dr, New Albany		E to W	Bright with tail and smaller fragment falling
7	Otisco	2 explosions		Explosion and rumble, time delay
8	Oakwood subdivision, New Albany		W	Bright red with tail
			KENTUCKY	
9	Prairie Village, Crestridge Dr	Nil	N overhead	Fireball with tail, left white trail and disappeared, like sparkler leaving small pieces
10	Valley Station, Dixie Hwy & Miller Ct	Nil	E to W	Basketball-sized fireball with red tail, detonation at endpoint
11	Holsclaw Hill, Brooks	Thunder 60 sec after sighting	E to W	Yellow, 3 fragments with 1 piece off each side, cone-shaped, 2 sec duration, 8,000–10,000 feet elevation
12	Okolona	Boom	E to W	Round, red fireball ca. 3 feet in circumference with red tail "about 10 feet long"
13	Bullitt Co. ca. 8 km from Shepherdsville	Boom		Swishing sound
14	Bullitt Co. south of Salt River		NW overhead	Blue corona on fireball with bright tail, burned out after 10 sec
15	Radcliff	Nil	NW	Silvery, elliptical vapor trail flame, no fragmentation
16	Radcliff	Nil	E to W	Yellow streak, bright explosion and disappeared
17	Elizabethtown	Nil	N	Ball of fire, low
18	Hodgenville		N	Reddish-yellow fragmentation at endpoint, became smaller and disappeared
19	Hodgenville	Nil	E to W	2 fragments, left trail of black smoke and fire during fall
20	Wax, Grayson Co.	Nil	E to NW	Dark in front, trail of fire red–white–blue
21	Between Bowling Green & Park City	Nil	W	Golden streak across sky
22	New Haven	Boom	E to W	
23	Boston		W	Fireball with orange trail, fire went out
24	Shepherdsville	Boom	E to W	Yellow and blue, 4–5 sec lag between sighting and noise

TABLE 1.—CONTINUED

	Observer location	Sound	Direction of flight	Comments on meteorite
25	10 km east of Taylorsville	Nil	E to W	Shining in front with flames coming from back
26	Pewee Valley	Boom	E to W	Clear color with tail
27	Oldham Co. between Crestwood and Ballardsville	Overhead boom		One loud explosion from directly overhead
28	Fox Harbor, Prospect Hwy 42	Boom–sizzle	NE to SW	Ball of fire, 500–1,000 feet high
29	Frankfort	Nil	W	Ball of fire with orange and yellow tail
30	Lexington		E to W	Ball of fire with tail, silver
31	Lexington, IBM	Nil	NE to W	Reddish-orange, very bright with trailing fire giving off objects, multiple fragmentation
32	Lexington (SW)	Nil	W	Grapefruit-sized, 2–2.5 sec, brighter than sun, white with yellow tail
33	E of Winchester on Mountain Pkwy	Nil	W	Reddish-orange with tail, 1532 hours
34	Somerset	Nil		Light flashing through sky at 1530 hours, shooting star
35	Somerset	Nil	E	Red, blue trail

the end point of the fireball were measured with a Brunton compass and/or a transit at the exact spot of observation. The bearing lines (Fig. 2) were plotted with a protractor on a detailed street map of the city showing the exact locations of all observations. The end result of such a survey can be used to establish the points formerly occupied by the fireball (Folinsbee and Bayrock 1964). The presence of the pronounced clustering of sightings at 4 widely separated locations strongly supports the sound data of at least 4 major detonations (Figs. 2, 3).

Spatial relationships of the various observers (35) and the direction of fireball approach, approximately S 87 W (Fig. 1), and the descriptions (Table 1) indicate that the outer limits of the reliable sightings are at about a 160-km radius from Louisville (Observer No. 1 in Indianapolis to the north; Observers Nos. 21, 34, and 35 to the south and southeast, and Observer No. 33 to the east). The audible outer limits of the detonations appear to be about 50 km from Louisville. Because the Louisville meteor fell during the daylight hours on a very clear, sunny, and cold day (–5.5 C), some eye witness accounts of the fall were very descriptive.

Observer No. 12 (Fig. 1) at a distance of 16 km reported, "A round red fireball about 3 feet in circumference with a fiery red tail about 10 to 12 feet long, moving from east to west, with no noise, lower than a plane would be, and then a boom." Observer No. 15 at a distance of 50 km reported, "It was a silvery, elliptically shaped vapor trail with flame, no noise." Observer No. 18 at a distance of 76 km reported, "A reddish-yellow fireball that became smaller, spitting particles, and then disappeared." Observer No. 19 at a distance of 60 km reported, "My father and I saw the meteorite while cutting wood about a mile south of Lincoln's birthplace in Hodgenville, Kentucky. My father saw one piece fall off first and then told me to look, and we both saw a second piece fall off. It left a trail of black smoke. They looked like fire as they fell. It was moving very fast, but we didn't hear the boom." Observer No. 20 at a

TABLE 2.—REPORTS ON FIREBALL OF LOUISVILLE METEORITE, 31 JANUARY 1977, BY OBSERVERS IN LOUISVILLE, KENTUCKY. SIGHTINGS ARE AZIMUTHS AT FIRST AND LAST OBSERVATION. FIGURES IN PARENTHESES ARE MEASURED ALTITUDES. OBSERVER LOCATIONS ARE FOR FIG. 2

	Observer location	Sighting		Duration (sec)	Comments
		First	Last		
1	4th & Liberty Sts	N 25 E (65°)	NW 65	3	Stream of fire; horizontal Roman candle; black object falling at 1,000-ft elevation; sounded like rocket fire
2	Browns Lane & Beargrass Creek	N 25 W (50°)	N 45 W (40°)	2–3	Blue–orange tail; slope >45°; sizzling hiss ca. 120 sec prior to large boom; disappeared after 30–45 sec
3	Bellarmine College	N 42 E (24°)	N 13 W (36°)	5	Fireball with orange tail; fragmentation, minor slope; sonic boom after 30–60 sec; like airplane on fire
4	27th floor, 5th & Main Sts	N 90 E (21°)	Overhead	2	White center with trailing yellow edges; 1 fireball maybe splitting; estimated 500–1,000 ft above tower
5	Preston & Eastern Pkwy	N 50 E (40°)	N 45 W (55°)	few	White nucleus with yellow tail; black smoke; 3 faint booms ca. 40 sec after first sighting; downward slope; like flag flapping in wind
6	Outer Loop & Smyrna Rd	N 18 E (21–25°)	N 45 W (19°)	5	Reddish with sparks; roll of firecrackers
7	6100 Campground Rd	N 43 E (19° 34′)	N 33 E (16° 35′)	few	Very bright explosion; bright orange and yellow; many fragments burned out at 2,000 ft; steep slope
8	4562 Melton Ave	N 47 E (22°)	N 15 W (14°)	few	Rolling thunder and boom 30 sec after first seen; 1 large fireball with orange tail and sparks; 3 explosion-like events, 1 ca. N 25 E large piece (ca. ⅓ of original) shot upward, 2nd halfway on trajectory, 3rd was shower at endpoint
9	3750 Crittenden Dr	E to NE (33°)	N 30 W (45°)	5	White with 2 streaks for 4 sec; completely extinguished white flame; sound like welder's torch and rolling thunder after 10 sec
10	Bremmer Way & Ehrler Dr	N 65 E (37°)	N 37 W (30°)	few	Very bright with orange tail; last noise about 60 sec after first seen
11	Washington & Ohio Sts	N 75 E (27°)	Obstructed (45°)	4	White with orange tail; fragmentation at endpoint; "crack" when exploded
12	8th & Broadway	N (55°)	N 75 W (27°)	4	Arc of welder's blowtorch; bright white with darker endpoints of cylindrical fireball; fragmentation (3) pieces fell N of Broadway at endpoint; static sound like rushing artillery shell overhead 60 sec after first seen; vanished then reappeared
13	1235 S. 3rd St 10th floor	S 80 W (5°)	S 65 W (5°)	few	Level flight of white to red fireball (maybe fragment reported in Lake Dreamland area but not recovered); sound before sighting
14	25th & Lee Sts		N 30–45 W (50°)	few	White streak; boom 30 sec after first seen; other explosions
15	1130 St. Michael St	N 40 E (20°)	N 70 W (20°)	2	Blue–white with orange tail; no fragmentation; huge boom ca. 60 sec after first seen; floor of house shaking

TABLE 2.—CONTINUED

	Observer location	Sighting		Duration (sec)	Comments
		First	Last		
16	3901 Taylor Blvd	N 25 E (30°)		2	White, very bright orange tail; no fragmentation; coneshaped; at least 3 booms, last 30–45 sec after first seen
17	7th & Berry Sts	N 50–65 W (45°)	N 75 W (40°)	2	White, like 2 fragments, small one preceding large one, both conical; largest boom like rumbling thunder
18	1821 Cypress St	N 80 E (25°)	NW	few	Fireball with yellowish parts and tail; 2 pieces, smaller one following; large boom
19	530 Camden	N 45 E (44°)	N 10 W (52°)	2–3	White–yellow like flare gun; 2 fragments, smaller preceding; popping to fizzling
20	1123 Standiford Lane	N (50°)	N 5 W (50°)	2	White flash with trail; noise continuous; no sound at endpoint
21	4th & York Sts	N 62 E (35°)	N 55 W	3	White with red tail; horizontal cone ca. size of quarter
22	Floyd & Walnut Sts	N 50 E (50°)	N 5 E (55°)	2	Pink nucleus with white exterior and gray tail; shaped like tennis ball; explosion at endpoint with 2 major fragments and tail of showers

distance of 104 km reported, "It was dark in front, coming from the east, red–white–blue with a trail of fire." Observer No. 29 at a distance of 64 km reported, "It was a ball of fire with tail, some orange and yellow and no noise." Observer No. 30 at a distance of 110 km reported, "It looked like a ball of fire, silverish colors with a tail, and was moving very fast." Observer No. 31 at a distance of 110 km reported, "A reddish orange, large and very bright meteor, trailing fire tail, giving off small objects, travelling westerly with a high rate of speed." Observer No. 32 at a distance of about 110 km reported, "It is brighter than the sun, moving in the same direction he was, low and fast, for about 2 seconds, appeared to be the size of a grapefruit, white with yellow tail, and horizontal flight." Observer No. 34 at a distance of 165 km reported, "A light flashing down through the sky. My first comment was I have never seen a shooting star at daytime before. My second comment was that it must be a piece of space junk burning up as it reentered the atmosphere. Would it be possible to see it this far away?" An observation at a distance of 190 km (near the Kentucky–Tennessee border at Interstate 65) appears to be the outer limit of sighting.

The following are some of the more important eyewitness accounts and are presented in chronological order of data gathering (Fig. 2).

Observer No. 4 in his office window, at the 27th floor of the First National Tower at Fifth and Main Streets, Louisville, provided an excellent head-on report of the fireball passing within an estimated few hundred feet of the window. "It had a very white center, with a pale yellow edge, and very little tail was visible from this position."

Observer No. 5 reported, "I walked a few steps upon entering the parking lot, and heard a flapping sound coming from the sky. I use the word flapping sound because the sound reminded me of a flag being whipped about by the wind. I looked up and saw a white, yellow-tinged fireball with a short tail, and some whisps of black smoke trailing it."

Observer No. 6 gave the following account of the fireball: "It was traveling in a northwesterly direction, first observed at approximately 25 to 30 degrees up in the sky, visible long enough to see it was a red

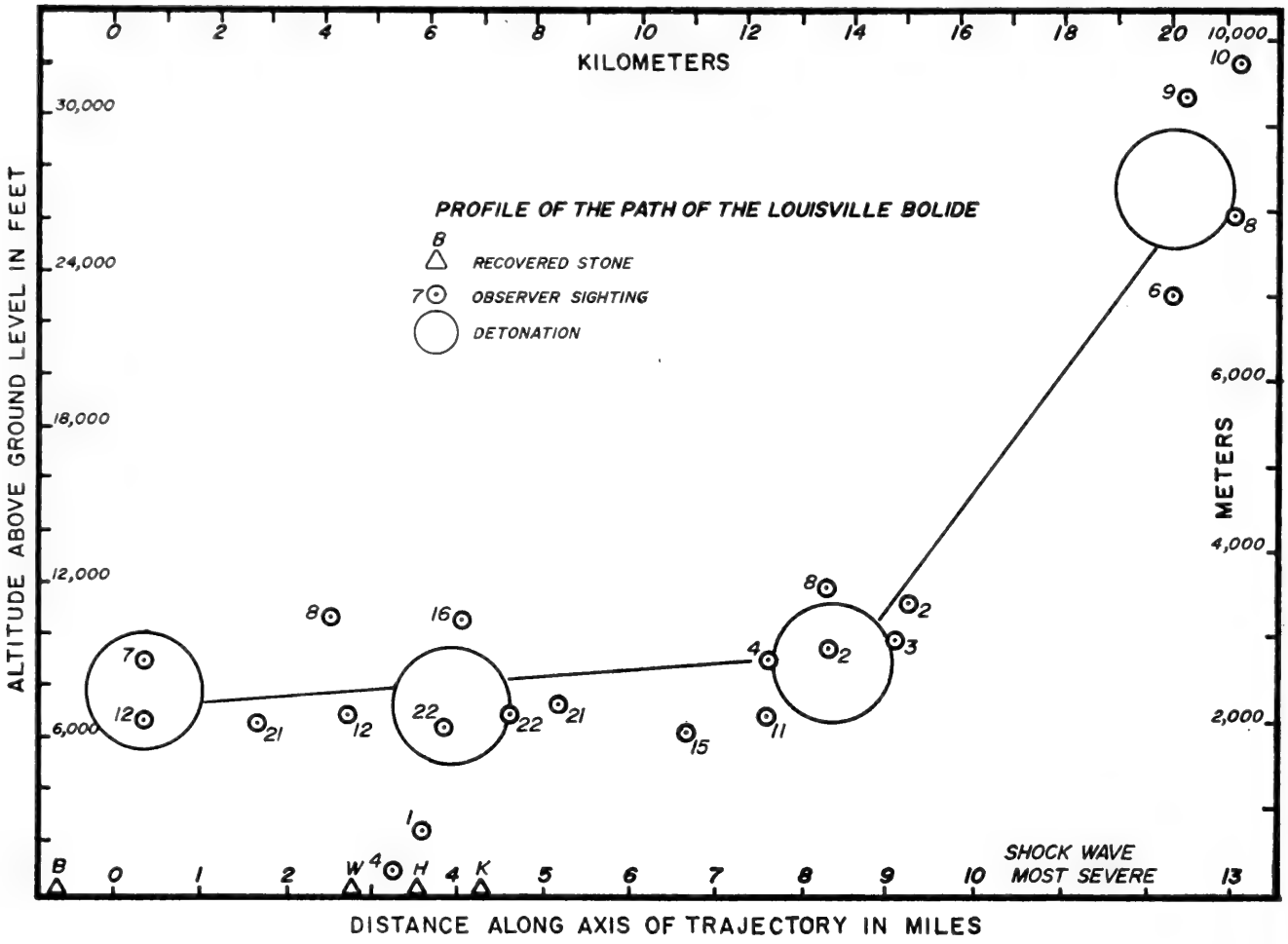

FIG. 3. Profile of the path of the Louisville Meteorite.

ball with sparks tapering out into a tail. Then it disappeared. Just a very short time after, the sound was like a roll of firecrackers exploding in about the same spot."

Observer No. 8 sighted a white fireball with a red tail that appeared to undergo 3 main fragmentation events over a ground distance along the axis of the trajectory of about 18 km, suggesting a slope of about 34°, and a velocity of about 3 km/sec near the end point. He noticed that, "At the point of the first fragmentation event, about one-third of the total mass shot upward and another blast occurred about half way along the slope with a final shower at the end point of the sighting."

One of the best descriptions of entry came from a geology student, Darren Doderer, working in the basement of the library of the University of Louisville who reported, "At 3:30 p.m. Monday, the 31st of January, I was sitting at a desk studying, and looking out the north-facing window of the library when I first noticed the meteor in a direction just north of east and at an altitude of about 30°. My initial impression was that the meteor was actually some type of firework shot into the sky from the field between the Gym and Threlkeld Hall. When I realized that it was not falling back to earth, but was instead moving laterally across the sky, I followed its course with closer attention. At no time did the object ever appear to grow larger as if it were falling towards the earth. The size remained uniform (roughly the size of a softball at a short distance), even though I was visually aware of the lack of depth perception. Its speed was noticeably slow, calculated velocity at 1 to 2 miles per second near the end point, it remained within my vision for 7 to 10 seconds. The color was white and

its shape was that of a compressed cone or funnel with the sharp end pointed away from the direction of travel. Both of those properties remained constant while the object was within my vision. The object's path took it over the western end of the library, and out of my field of vision. About a minute and a half later I heard a large explosion, comparable to explosions produced by the artillery at Ft. Knox."

Interpretation and Reconstruction of Sighting Data

Sighting directions, locations of detonations, fall area, and the area of most severe ground shock on the basis of selected field interviews are shown in Fig. 3. The most reliable observers were those closest to the path, and Observer Nos. 1, 2, 3, 4, 7, 8, 11, 12, 15, 21, and 22 provided most of the details in identifying the profile. The apparent angle of descent was about 35° as reported by Observer Nos. 2 and 8. Observer No. 8, an amateur astronomer witnessed most of the trajectory and fragmentation events. Apparently, there were few observers who actually witnessed the entire sequence of events from the first illumination or detonation up to the end point or final disappearance of the fireball. The largest number of observations were made by those south of the fireball trajectory, and who did not have to face the glare of the sun's rays.

Apparently, the bolide created its initial bright flare above the observers east of St. Matthews. Observer Nos. 6, 8, 9, 10 (Figs. 2, 3) first noticed the bolide at an altitude of about 9 km. This calculation of altitude of first disruption is somewhat lower than the "normal" altitudes of 12 to 30 km as reported by Krinov (1960) and the altitudes near 30 km for Canadian chondritic meteorites (Folinsbee et al. 1969). Because the detonation of a bolide is so spectacular, one would assume that the trajectory can be pinpointed in angle and direction by cross sightings. Plots of altitudes of the moving bolide were calculated by multiplying the tangent of the vertical angle times the ground distance (as computed from the site of the observers).

After the first illumination, the main body appeared to continue on essentially a course of about S 87 W. The sighting and sound data suggest that a second major detonation took place about 3 km over the heads of the people in the St. Matthews area, including the senior author's house. The atmospheric shock wave in that area appears to be the most severe, rattling windows, knocking pictures off walls, and causing minor damage to a chimney.

The angle of descent changed markedly subsequent to the second detonation (Observer Nos. 2, 8), and the body took on a more level flight. A third detonation apparently occurred above the intersection of Interstate 65 and Main Street, Louisville, sending fragments directly at the city (Observer Nos. 4, 8, 22). It is tempting to speculate that 3 of the 4 recovered stones were the result of that detonation. It is noticed that the slope should become shallower as the small mass reacts to the shock disturbance of the air, implying fragmentation of the meteorite (Hellyer 1969).

The final and fourth detonation apparently occurred above the intersection of 45th Street and Broadway, 2 of the busiest streets in western Louisville. That detonation was witnessed by Observer Nos. 5, 6, 7, 9, 12, and 14 (Fig. 2). The Barlow stone was recovered in that area.

A best fit interpretation and reconstruction of the fireball's trajectory suggests that the meteoroid attained a fairly level flight at an altitude of about 2 km between the last 3 detonation points subsequent to undergoing a very steep slope of about 35°. Estimates of the duration of the fireball vary from about 2 to 6 sec indicating a very slow velocity of about 2 km/sec along the last 20 km of its trajectory. Observer No. 6 noted a 5-sec duration over about 19 km, Observer No. 9 gave 6 sec for 19 km, and Observer No. 12 gave the length of time the fireball was in sight as 4 sec for 5 km near the point of final disappearance of the fireball.

Sound Data

Detonations accompanying the Louisville fireball were heard throughout the fall area, but the audible limit was greatest to the southeast, probably as a result of the 90-knot winds from the northwest (Table 3). Four major detonations were reported, but their number and character varied from one observer to another depending largely on location. In the area of first detonation to the area of second detonation, the initial entry of the meteor probably produced the largest shock wave (similar to sonic boom), possibly due to the highest velocity through the air attained by the original body. Sounds heard by observers varied from one location to another. Observers closest to the path described a hissing to a sizzling sound. Other close-in descriptions included: sounds resembling roman candles, artillery shells, welder's blow torch, rushing winds, thunder rumblings, roll of firecrackers, and rocket fire. One observer (No. 5, Fig. 2) suggested that the sound was much like a flag "flapping in the wind."

The time interval of 60 sec between first seen and the first sound arrivals suggests that the sound waves traveling at about 0.3 km/sec originated at an altitude of about 9 km. Therefore, the sound data agree quite favorably with the sighting data. Many observers used the word sonic boom for a description of the sounds that they heard. Apparently, sonic booms may be produced when the bunching of the aerodynamic disturbances that the meteorite creates is at the same speed of the meteorite (Warren 1977). Such aerodynamic disturbances will travel out in all directions, and the observer will notice the booms whenever the component of the velocity of the meteorite towards him is equal to the speed of sound.

Color and Form

Analyses of the information from the different observers indicate that the bolide was blue–white, detonated with flashes of white light, traveled as a reddish fireball, and became black when it reached terminal velocity as the fragment falls almost vertically to the earth. Air resistance slows down most meteorites to a uniform terminal velocity about 100–300 m/sec (Krinov 1960).

Table 3.—National Weather Service Report from Standiford Field, Louisville, Kentucky, 31 January 1977. Clear, wind from west at 10 miles/hour, temperature 22 F, relative humidity 51%. Wind velocities from National Weather Service

Altitude (feet)	Speed (knots)	Direction (from)
34,000	80	W 270°
24,000	90	NW 290°
16,000	60	NW 300°
14,000	50	NW 300°
9,000	40	NW 300°
5,000	35	NW 390°
	Surface boundary	
2,000	30	W 270°

Apparently, the Louisville fireball flared a very bright blue–white to silvery color at speeds where the kinetic energy per ounce was enormous. That energy would be dissipated within a very few seconds by pushing the air aside and heating the surface of the meteoroid. This produced a glowing tail of air behind with some of the ablated material of the meteroid. A color change from white to red of the detonated fragment apparently took place as the fragment approached ground level (Folinsbee and Bayrock 1961).

Observers described various shapes for the bolide depending on what part of the fall witnessed, detonation, level flight, or the approach to ground level of a particular meteorite. Observer No. 12 (Fig. 2) suggested that the bolide was cylindrical in outline and resembled an artillery shell that he observed during his army career. During the higher atmospheric altitudes, the bolide was described in size and shape as a grapefruit, tennis ball, cone shaped, or a fireball.

Recovery

The total amount of Louisville meteorite material that reached the ground is not known. Some may still be lodged in some-

one's roof, or perhaps be lost at the bottom of the Ohio River. Approximately 25 percent of the ellipse (Fig. 2) is the Ohio River, that was frozen over at the time of fall. Most of the likely places of thin ice area were investigated because some meteorite recoveries have been made from lake ice and specimens that may still be found would change the fall area.

From 1 February to 30 March 1977, the senior author, students, and others conducted ground searches. Approximately 2,560 man-kilometers were used in checking out possible fall areas where there was a lead to a possible find. Ground searches were complicated in the heavily populated area of western Louisville by the improbable task of checking out all the roof tops in the area. Most public property in the western end of Louisville including Shawnee Park, Shawnee Golf Course, Chickasaw Park, and others were investigated. In some cases, the search party was enlarged by the owners and occupants of the search area. Permission to conduct ground search was obtained from various residents of Indiana. The grounds of the Gallagher Plant of Public Service Indiana, on line with the path of the fireball, were searched.

The open areas along the River Road on the western bank of the Ohio River were also traversed on foot, but to no avail. Several cross sightings in the southwestern and northeastern parts of the map area (Fig. 2) prompted numerous empty-handed recovery efforts. A systematic sweep of the area adjacent to the grounds of Stauffers Chemical Plant and the area to the northeast of the Barlow residence proved unsuccessful. Observer Nos. 7 and 12 were convinced that recoveries were possible at the point near the intersection of their cross sightings. Some of the local people were shown the meteorite and encouraged to do some searching. However, the "front page coverage" of the press, television, and radio probably was responsible for the recovery of the 4 stones. Approximately 200 possible meteorite specimens were turned in for identification, but no new recoveries were made after the first week.

To date, 4 widely separated stones of the Louisville meteorite with a total weight of 1,312 g have been recovered (Figs. 2, 3, Table 4).

The first stone recovered was a 1,051-g piece from the roof of the residence of Mr. and Mrs. Robert Barlow at 4509 Greenwood Avenue, Louisville. Mrs. Barlow reported that she had heard the meteorite hit the roof of her house after hearing a large explosion. She remarked that, "the sonic boom sounded like thunder, and the second noise sounded like maybe some ice had fallen." When her husband came home, he noticed a hole about 1 m across in the roof, and immediately called the roofer who realized the scientific importance of the fall by notifying the manager of Television Channel 32, Louisville, that he believed the roof he had repaired had been damaged by a meteorite. The authors were called in at this time to identify the meteorite, inspect the damage at the Barlow residence, and to look for any other fragments. The stone had lodged itself in the roof (shingles covering 7.5-cm by 2.6-m boards), allowing the exterior surface of the stone to pick up some tar from the shingles. A shock wave from the impact apparently had penetrated about a meter of attic space and then registered its force on the ceiling of an upstairs closet by knocking down a 100-cm^2 slab of plaster.

The Rauch Planetarium received a telephone call from Mrs. Margaret Krill of 906 Ellison, Louisville, and she reported that a stone (36.5 g) had broken her window at about the same time that she heard a loud boom overhead. Hunt identified the stone as being part of the same Louisville meteorite.

The third recovered stone was found on top of a car belonging to Mrs. Marcella Horney parked at 100 East Liberty Street, Louisville. Apparently the stone caved in the car roof and then bounced to the hood of a nearby car. The stone was identified by Hunt at the Rauch Planetarium.

The fourth meteorite apparently had knocked a 5-inch hole in the roof of the R. L. White warehouse at 1023 West Main Street, Louisville. It lay unnoticed on the

TABLE 4.—PETROGRAPHIC DESCRIPTIONS OF 4 STONES RECOVERED IN LOUISVILLE, KENTUCKY, FOLLOWING THE FALL OF THE LOUISVILLE METEORITE 31 JANUARY 1977. MINERAL COMPOSITIONS ARE FOR A THIN SECTION OF THE BARLOW STONE AND FOR HAND SPECIMENS OF THE OTHERS. L-1 = BARLOW STONE, L-2 = KRILL STONE, L-3 = HORNEY STONE, L-4 = WAREHOUSE STONE

Specimen no.	L-1	L-2	L-3	L-4
Size	10 × 10 × 8 cm	3.5 × 3 × 2 cm	7.5 × 4.5 × 3.5 cm	4.5 × 3 × 2 cm
Weight	1,051 g	36.5 g	195 g	30 g
Locality	4509 Greenwood Ave	906 Ellison Ave	100 E. Liberty St	1023 W. Main St
Recovery date	31 January 1977	2 February 1977	4 February 1977	5 February 1977
Macroscopic features	Light, 75%; dark, 25%			
Color				
fresh surface	Light gray–green	Light gray–green	Light gray–green with darker parts	Minor dark gray shock material
exterior	Dark gray crust, some tar from roof	Rounded, ablated fusion crust, very thin, 30%	Rounded, ablated fusion crust, 30%	Light gray–green with dark gray fused crust (40% of surface), small pits in crust
Grain size	Light portion fine grained av 1 mm, porphyritic	Fine grained	Fine grained av 1 mm	Fine grained up to 1 mm
Texture	Gabbroic, equiangular	Gabbroic to banded parts	Gabbroic	Gabbroic
Structure	Possibly 2 bodies separated by a band of dark shock material or foliation within 1 body	Shock material 25%	One-quarter of aerolite, aerodynamically rounded, lineated parts few mm, some dark shock material	Ablated aerodynamically, lineated voids–softer minerals–carbon? (one-half aerolite)
Mineral composition				
Chondrules present	10% (boundaries are diffuse)	10%	Less than 10%	Less than 10%
Color minerals	Light gray olivine, barred orthopyroxene	Light gray olivine	Light gray olivine	Light gray olivine

warehouse floor until a security guard recovered the stone near the spot where the roof was leaking. Positive identification of the stone was made by Hunt.

Morphology and Macrostructure

All stones of the Louisville meteorite have a partial fusion crust, are dull grey–green in color on a freshly broken surface, are aerodynamically rounded; magnetic, very hard, and banded in part. Because the meteorite was recovered soon after the fall, the exterior morphology is still characterized by flight markings. The fusion crust that forms during flight is black, vesicular, and up to several millimeters thick. The thinner crusts may have formed in the breaking period of flight. The scattered accumulations of fusion crust over most of the exterior suggests that each stone was once part of a larger mass that tumbled in flight. Because of the rounded nature of the stones, it would appear that a significant amount of ablation or rounding took place during oriented flight. All the stones have surfaces that look like freshly broken rock. This suggests that each recovered stone represents material that broke away from a much larger piece late in atmospheric flight, possibly at the final end point of the fireball.

It is noted that the Louisville meteorite may have undergone a certain degree of shock metamorphism as indicated by the dark bands forming up to 25 percent of the meteorite. Mason (1966) and others have suggested the light and dark color variation may be explained by metamorphic processes acting on chondritic material. The dark bands are characterized by considerable "veining" of the metallic minerals and breccias. The Warehouse stone shows a fine network of cracks or lineated voids that may be external expressions that have penetrated into the interior of the stone (Clarke et al. 1971) or may represent the action of the removal of softer parts of the stone at the time of detonation.

In thin section, the Barlow stone shows some obliteration of the primary textures, that is, there appears to be a general merging of the matrix and the chondrules. The chondrules appear deformed because of their elliptically shaped outline. Some are partially disrupted, and undulose extinction is common. Chondrules of barred olivine and pyroxene are diffuse in part, but most are recognizable. They show a limited range of radii within the thin section and the average diameter of the chondrules is about 1 mm. Other types of chondrules include radiating, monomineralic, and rhombic pyroxene types. Lithic fragments of chondrules are present.

FIG. 4. The Krill Stone of the Louisville Meteorite showing the partial fusion crust.

The Krill stone (Fig. 4) shows partial fusion crust and some veining. A thin section of the Barlow stone (Fig. 5) contains (a) a disrupted chondrule, and (b) a chondrule merged with the matrix.

Further Investigation

The largest recovered stone of 1,051 g, referred to as the Barlow stone, reached the Smithsonian Institution Division of Meteorites on Friday, 4 February 1977. The information of the recovery was given to the staff of the Scientific Event Alert Network (SEAN 2:14). A 107-g slice was cut at the Smithsonian for mineralogical and chemical investigations after an initial slice

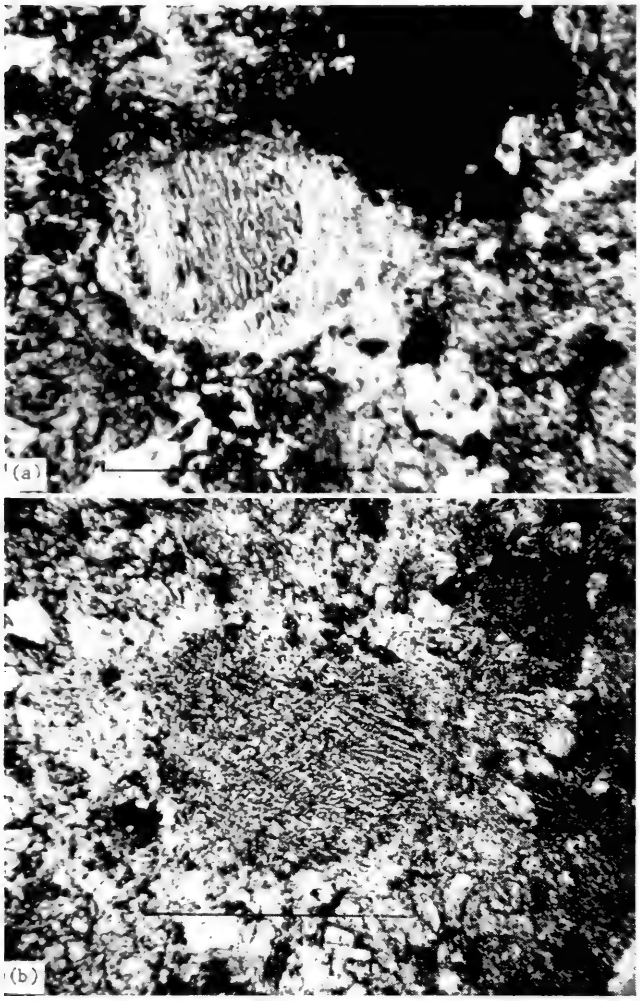

FIG. 5. Photomicrographs of a thin section of the Barlow Stone showing (a) a disrupted chrondrule and (b) a chondrule merging with the matrix. The scale bar in each photomicrograph is 1 mm.

TABLE 5.—CHEMICAL ANALYSIS OF THE LOUISVILLE METEORITE, USNM 5872 (LIGHT). ANALYST: EUGENE JAROSEWICH, DEPARTMENT OF MINERAL SCIENCES, SMITHSONIAN INSTITUTION, WASHINGTON, D.C.

Chemical	%
Fe	5.85
Ni	1.23
Co	0.06
S	(1.76)
FeS	4.83
SiO_2	40.73
TiO_2	0.13
Al_2O_3	2.22
Cr_2O_3	0.55
FeO	15.09
MnO	0.36
MgO	25.45
CaO	1.80
Na_2O	0.96
K_2O	0.11
P_2O_5	0.19
$H_2O(+)$	0.12
$H_2O(-)$	0.03
C	
Total	99.71
Total Fe	20.65

of about 50 g was cut by the authors at the University of Louisville.

The bulk chemical analysis by Eugene Jarosewich of the light portion of the Barlow stone is given in Table 5. The chemical data (Fe/SiO_2, Fe°/Fe, and SiO_2/MgO ratios) and petrologic data indicate that the Louisville meteorite is an olivine–hypersthene chondrite (L6 in the classification of Van Schmus and Wood 1967).

After the 2 slices of 50 g and 107 g were removed from the Barlow stone, the butt piece was flown to L. Rancitelli of Batelle Northwest, Richland, Washington, for the nondestructive measurements of rapidly decaying radionuclides. This may be one of the fastest times on record for a meteorite to undergo radioactive counting subsequent to a fall. The wholebody counting of the very short half-lives gives information on cosmic radiation that will complement measurements made in other similar investigations. Preliminary data of this type suggest that the entire original Louisville body was 10 to 100 times as large as its recovered pieces.

Specimen material of the meteorite was made available for measurements on argon isotopes and other rare gases at the Department of Earth Sciences, State University of New York, Stony Brook. Those measurements may also give some information on the preatmospheric size of the body. Radiometric ages of both the light- and dark-colored portions of the meteorite suggest that the time of shock metamorphism was several million years ago (private communication).

LITERATURE CITED

CLARKE, R. S., E. JAROSEWICH, AND J. NELEN. 1971. The Lost City, Oklahoma, Meteorite: an introduction to its laboratory investigation and comparisons with Pribram and Ucera. J. Geophys. Res. 76:4135–4143.

FOLINSBEE, R. E., AND L. A. BAYROCK. 1961. The Bruderhein meteorite—fall and recovery. J. Roy. Astro. Soc. Can. 55:218–228.

————, AND ————. 1964. The Peace River Meteorite: fall and recovery. J. Roy. Astro. Soc. Can. 58:109–124.

FOLINSBEE, R., L. BAYROCK, G. CUMMING, AND D. SMITH. 1969. Vilna meteorite—camera, visual, seismic and analytic records. J. Roy. Astro. Soc. Can. 63:61–86.

HELLYER, B. 1969. Statistics of Meteor Falls. Earth Planet. Sci. Lett. 7:149–150.

HUNT, G. 1977. Louisville Meteorite, ordinary chondrite L6 with shock metamorphic textures. Amer. Astron. Soc. Bull. 9:506.

KRINOV, E. L. 1960. Principles of Meteorites. Pergamon Press, New York, N.Y., 535 pp. (Russian original published in 1955).

MASON, B. 1962. Meteorites. J. Wiley & Sons, Inc., New York, N.Y. 274 pp.

————. 1966. The enstatite chondrites. Geochim. Cosmochim. Acta 30:23–39.

PRIOR, G. 1953. Catalogue of meteorites. 2nd ed., rev. by M. H. Hey. London: British Museum.

SCIENTIFIC EVENT ALERT NETWORK BULLETIN. 1977. Smithsonian Institution 2(1):14.

SMITH, J. L. 1877. Description of meteoric stones: Cynthiana, Kentucky meteorite. Amer. J. Sci. Third Series XIV:224–229.

VAN SCHMUS, W. R., AND J. A. WOOD. 1967. A chemical–petrologic classification for the chondritic meteorites. Geochim. Cosmochim. Acta 31:747–765.

WARREN, C. H. E. 1977. Sonic bangs. Contemp. Phys. 18:183–192.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 54–59

Sociology and Policy: The Clark Maritime Centre Environmental Impact Assessment[1]

John A. Busch
Department of Sociology, University of Louisville,
Louisville, Kentucky 40208

Introduction

Can research and opinion of sociologists influence governmental policy and decision making? One possible avenue for such influence is the Environmental Impact Statement (EIS). The potential for influence through that channel would appear great, although it is as yet ill defined and beset with problems. This paper attempts to raise some questions that must be answered eventually, and to point to some problems that must be solved concerning the sociological aspects of impact statements, using a specific example, The Clark Maritime Centre. Issues to be addressed include (1) near-site surveys, (2) the community leaders survey and quantification, and (3) vested interests of the coordinators of Environmental Impact Assessments (EIA's).

The distinction between an Environmental Impact Assessment and an Environmental Impact Statement is, I believe, a very important one, the implications of which will be taken up further on. At this point, it will be sufficient to say that when a decision is made that a formal Environmental Impact Statement is needed, it is supposed to be based on the gathering and analysis of appropriate data, termed the Environmental Impact Assessment (U.S. Army Corps of Engineers 1974). The federal agency responsible for producing an Environmental Impact Statement under the National Environmental Protection Act of 1969 either conducts the assessment itself or contracts for some reliable agency to do it. The Environmental Impact Statement is then written from the assessment, a fact that gives the federal agency a means of controlling what is finally presented.

In the spring of 1975, I directed 3 surveys as part of an Environmental Impact Statement for a proposed riverport and industrial park on the Ohio River in Clark County, Indiana, the Clark Maritime Centre. The first, or near-site survey, was based on 15- to 20-min interviews with residents of 301 households near the proposed site. For the second, or on-site survey, a longer period was spent with residents of 9 of the 16 households on the proposed project site. The third survey used mail questionnaires sent to 34 persons in Indiana and Kentucky who had been nominated as influential residents of the region.

Near-Site Surveys

The sociological investigation for that statement was unusual in that a survey of opinion toward the project was made for the population living *near* but not *on* the site, as well as for those few on-site residents and a small number of local influential persons. Such a nontraditional approach provides reactions of a larger segment of the population near the proposed project, rather than just of those who live on the site itself. The community attitudes toward a proposed project may or may not be consistent with those of the on-site residents who must give up their homes, but once such data are gathered, they demand consideration. The important policy question raised by this procedure concerns just how much weight should those community opinions carry in determining the desirability of a project.

Of course, the basis of opinion can vary considerably from one respondent to another, and from one study to another. Public

[1] Presented at the North Central Sociological Association Annual Meeting 6–8 May 1976, The Galt House, Louisville, Kentucky.

information and commentary prior to the survey may be lacking or abundant, but usually are biased. In the present near-site survey, respondents had some knowledge of the proposed riverport, but were essentially unaware that about 800 adjacent acres would be devoted to an industrial park. We showed our respondents a map of the immediate area and provided a short description of the proposed facilities. That and other techniques could be employed to help mitigate any presurvey publicity or propaganda. If the respondents are adequately informed, a stronger argument can be made that their opinions should carry significant weight, but how much weight relative to physical and biological impacts of the proposed project remains an open and difficult question. The sample survey is one thing many sociologists are well trained to do. Should such surveys become typically incorporated into Environmental Impact Statements, it is likely that sociologists would be called upon to conduct them, and would pressure them to consider more earnestly the weighting problem.

THE COMMUNITY LEADERS SURVEY AND QUANTIFICATION

The very existence of the Environmental Impact Statement requirement, mandated by the National Environmental Protection Act of 1969, is an indication of an emerging public concern for the quality of the human environment and the importance of those factors that must, by law, be addressed (Council on Environmental Quality 1973, 1974). The surveys of the on-site residents, near-site residents, and community leaders can all be sources of evidence that is either typically overlooked in the standard Environmental Impact Statement or is treated as peculiar to a particular instance. Perhaps the best example is the Community Leaders Survey. Community leaders usually are above average in intelligence, educational level, and knowledge of the inner workings of the community and its problems. In the case of the Clark Maritime Centre, as in most Environmental Impact Statements, community leaders were not sampled to determine the proportions holding various opinions, but to obtain as wide a variety of opinion as possible. Technical problems of sampling, as well as limitations of time and budget, force the researcher to delimit the near-site survey so that many individuals with an interest in the outcome of the project, could not be sampled. Moreover, their opinions may be quite different from those of people nearer the proposed project site. The community leaders survey serves to recover some of that information, at least qualitatively, if not in a form amenable to quantification. How can these more elaborate and well thought out concerns of community leaders be entered into an Environmental Impact Statement, even though they may not be "quantifiable?" How much weight should they carry relative to the other surveys and relative to the massive amount of social indicator data, including archival material, that is quantifiable but often only crudely interpretable?

The well thought out concerns of the community leaders can be entered into the Environmental Impact Statement by making a detailed list of all issues pro and con that the survey director (not the Environmental Impact Assessment director) judges as (1) potentially significant additions to the issues already being addressed by the Environmental Impact Assessment and (2) reflections of a trend of feeling in the population in a somewhat larger area than the near- or on-site populations. Both points are pertinent to the case of the Clark Maritime Centre. For the Clark project, both the on-site and near-site surveys were conducted solely in Indiana, while the community leaders survey encompassed the Greater Louisville region, thus including sentiment on the Kentucky side of the river. This latter survey revealed some concern for the status of Six Mile Island, immediately adjacent to the project and owned by Kentucky. Furthermore, there was a noticeable concern over property values on the Kentucky side of the river. Of course, many comments were made in support of the project. A few negative comments empha-

TABLE 1.—PERCENTAGE OF SPACE DEVOTED TO SELECTED SOCIOLOGICAL TOPICS LISTED UNDER "SOCIAL CHARACTERISTICS" IN THE CLARK MARITIME CENTRE FINAL DRAFT ENVIRONMENTAL IMPACT STATEMENT

Topic	Total
Population trends	27.8
Housing characteristics	19.0
Recreation	15.9
Public facilities and aesthetics	12.7
Near-site survey	19.0
On-site survey	4.0
Community leaders survey	1.6
Total[1]	100

[1] The total reflects only those topics in the tables.

size the usefulness of the community leaders survey as it draws from a wider geographic area and brings to light issues missed by the other surveys.

The question of weighting the community leaders survey relative to the other surveys and other quantifiable archival data, presented itself in the Clark project. There was no computational decision strategy or any guidelines for a judgemental strategy for those contingencies. As it turned out, the social impact of the project in the Final Draft of the Clark Maritime Environmental Impact Statement (U.S. Army Corps of Engineers 1975) was largely confined to population trends and housing characteristics, etc. in the area (with very little interpretation of the relevance of this information to the proposed facilities). In the 2 important chapters, Environmental Setting Without the Project and Environmental Impact of the Proposed Action, there was a marked imbalance between data and interpretation, coupled with the imbalance given to archival data versus the attitudinal data including the community leaders survey (Table 1). At least 2 possible explanations for such imbalances, suggest themselves: (1) when data are quantified (especially when elaborated by charts or tables) they tend to take on an aura of validity and importance that may be misleading for the issue at hand. If the relevant data are reported but not interpreted, they are, at best, mere *padding* and, at worst, a *token use of sociology* on nonsensitive issues to avoid its use on sensitive issues; and (2) perhaps in the confusion of trying to decide how to present the opinions of the community leaders, it becomes easiest to classify it into a few very large categories, consequently rendering it useless. This is a more benign cause, but has equally undesirable effects.

VESTED INTERESTS OF COORDINATORS OF ENVIRONMENTAL IMPACT ASSESSMENTS

A possible explanation of the imbalance in the presentation of different kinds of data revolves around the vested interests of the coordinators of the Environmental Impact Assessment. For example, if an engineering firm that hopes eventually to build the project is selected to conduct the assessment, there is a marked conflict of interest. That conflict would exist even if most of the research were conducted by subcontractors working under the direction of the firm with the vested interest. In the case of the Clark project, the community leaders survey offers a concrete example.

In surveying community leaders, we came across facts and concerns peculiar to the project at hand that were not addressed elsewhere in the Environmental Impact Assessment. Some of those issues were somewhat sensitive, and were effectively ignored in the First Draft of the Environmental Impact Assessment by categorizing them as opposition "based on recreational, environmental, aesthetic and economic reasons," and giving 6 illustrations of "typical concerns." The following are examples that perhaps should have been included as *additions* to issues raised elsewhere, either in the sense of not having been mentioned at all or as having been mentioned so briefly as to have missed the import of the issue for the project. Two that *favor* the proposed facilities were: (1) the facilities as planned would localize industrial development, and, (2) the area presently lacks sufficient industry to support required governmental services and consequently

such facilities would be desirable. In *opposition* to the proposed facilities were: (1) the fact that a community organization in Kentucky had gone to considerable lengths (including obtaining a grant from the U.S. Department of the Interior) to purchase and seek gifts of land to create a park along the river that would lose some of this scenic value if the riverport were built across from it, and (2) pleasure boating is as important to the local economy as the proposed Maritime Centre and business from pleasure boaters would decrease if the proposed facilities were built.

The point should be made that just because a respondent makes an assertion, that assertion is not necessarily valid and such a disclaimer should be included in each Environmental Impact Statement. Nevertheless, once the assertion is made and the issue is out in the open it can be investigated. This certainly is the value of the Community Leaders Survey. The question of who should investigate issues raised in the Community Leaders Survey that are not being addressed elsewhere has not been considered by those who have had the responsibility of preparing Environmental Impact Assessments or Environmental Impact Statements. The questions raised for the influence of sociology on policy include: (1) is mere lip service given to sociological analyses?, and (2) what is to prevent differential emphases on those areas of the analysis that reflect positively on the project from those that do not or vice versa?

If there are vested interests in the directorship, and should one of the surveys oppose one of those interests, the influence of that survey can be negated by mentioning it only superficially and by concentrating on more favorable findings. That devious practice would be less likely to succeed if there were guidelines for presentation of data and for interpretation of each kind of survey. The need for guidelines seems particularly urgent in the community leaders survey. When the data oppose the vested interests, there may be a temptation to present the findings in such a form as to make them meaningless. If the federal agency responsible for the preparation of the Environmental Impact Statement has no such guidelines, and its personnel are sufficiently overworked with other matters, they may find it easy to accept uncritically the judgment presented in the assessment.

Conclusions

At base, the issues raised here and the call for guidelines reveal that the decision making procedures in the Environmental Impact Statement are grossly underdeveloped. A society in which some important decisions are made solely on the basis of scientific studies, without the involvement of power and influence, might be difficult for many sociologists to envision. Yet, in a very real sense, the Environmental Impact Statement purports to be taking us in that direction. Even to approximate such an ideal would likely decrease inequities in power and privilege, but would benefit the environment. A survey by the Council on Environmental Quality (1975), of all federal agencies that have completed 100 or more Environmental Impact Statements, reported assertions by all those agencies that their decisions on various actions for which Environmental Impact Statements were made were substantially affected by the findings of the Environmental Impact Statements, either in terms of reversing or modifying those decisions. Hopefully, those reports have not been exaggerated and do indeed indicate a movement toward the ideal. It is my understanding that the federal agencies have been subjected to considerable public pressure to reform, including improvement and better disclosure of the decision making procedures for the Environmental Impact Statement. If that is true, then once again the public is ahead of the scientific community. But because of its special expertise, it is necessary for the scientific community to turn its attention to those issues before any reasonable resolution can be forthcoming.

It would seem that among many other things the *guidelines should emphasize the need to justify the relevance of any piece*

of sociological data for the proposed action at hand. Such an emphasis would decrease the tendency to "pad" certain data in order potentially to overshadow other data. The force of such a guideline extends all the way to the specific datum, rather than stopping with a justification for the general *type* of data. By way of illustration, it would not be enough for a justification to be given for different types of surveys (on-site, near-site, and community leaders, etc.) or other forms of sociological data (archival data, e.g., census data, other records that might be supplied by community planning agencies, etc.). Instead, the *specifics* must be justified. For example, the Council on Environmental Quality (1975) Guidelines suggest the use of population statistics in general. In the Clark Maritime Centre Environmental Impast Statement, space in terms of both text and tables is devoted to minority characteristics, age–sex characteristics, family characteristics, and school enrollment. There is no justification given for the inclusion of those data, i.e., their relevance to the proposed riverport and industrial park is not even alluded to. Those data are included in the section Environmental Setting Without the Project but not mentioned in the crucial section Environmental Impact of the Proposed Action. The actual inclusion in the Environmental Impact Statement of data on minority characteristics, age–sex characteristics, etc. needs some justification lest (1) they be used as padding to overshadow a less than thorough presentation of some other, less favorable, data, or (2) the quantity of uninterpreted data generates confusion for the reader or a hesitancy to go to the trouble of reading more than a summary of the document.

The influence of the Environmental Impact Statement director is strong but not all prevailing, as was indicated by the controversy over the inclusion of the On-Site Survey. The results of that survey were completely left out of the Environmental Impact Assessment submitted to the Corps of Engineers. Before the First Draft of the EIS was published, I raised objection to that deletion and in a meeting between myself, the Environmental Impact Assessment Director, and a Corps official, the issue was civilly but heatedly argued. As expected, the on-site respondents were generally opposed to the project. But what seemed to bother the Environmental Impact Assessment Director most was my insistence on including the assertion by one of the respondents that 3 of the families on the site are related and the heads of those households have been lifelong residents. Such an assertion, the Environmental Impact Assessment Director felt, appealed too much to sentimentalism. Yet, it would be hard to deny that the displacement of those families might well be perceived by them as adverse impact. It was the decision of the Corps official to include the assertion as well as the rest of the On-Site Survey.

My hope is that sometime in the future, sociologists will be able to look back at that particular Environmental Impact Assessment Director with a feeling of gratitude. As the unverified story goes, that man was able to sell the idea of a Near-Site Survey to his superiors in the face of great resistance. I don't know how to express strongly enough my conviction that the Near-Site Survey is immensely useful to the Environmental Impact Statement and *to sociology as a profession.* Certainly, there is expertise in survey techniques in other disciplines, but in the public mind and in the minds of some environmental impact assessment directors, surveys of social characteristics and attitudes will call for sociologists. For sociologists, the Environmental Impact Statement in general, and the Near-Site Survey in particular, can be a source of income, community service, and in some instances a source of data for their scholarly pursuits. If we become more involved as individuals with the Environmental Impact Statement, I think we would be well advised to enter early into the planning stage lest we find inadequate planning for any of the above possible benefits. My experience with the Clark Maritime Centre surveys convinces me that the knowledge of survey techniques by those who planned and budgeted the Environmental Impact Assess-

ment was nil. The funding was absurdly low and the time frames were quite unrealistic.

According to the Council on Environmental Quality (1975:412),

> "As the relevance of different types of information becomes apparent, the current approach of some agencies simply to catalog an enormous variety of facts should slowly begin to change. Many impact statements now resemble encyclopedias. They discuss the project's setting in overly elaborate detail and contain lengthy descriptions of all species of plant and animal life in the affected area. Frequently, this reflects a lack of understanding of what is important and what is not. As the crucial environmental questions start to come into focus, it should become increasingly clear that much of this verbage can be dispensed with, thus helping to reduce the size of many of the statements."

Obviously, sociology is not the only discipline in an ambiguous situation with respect to its contributions to environmental impact statements. The Environmental Impact Statement is going to become important to the sociologist as a source of income and as a tool for influencing social policy. Whatever the problems with the way sociology is used in the Environmental Impact Statement (be those problems of uncertainty only, or of the temptation to distortion by vested interests able to work their will in the midst of uncertainty), it is time that sociologists advocate a set of procedures for the presentation of sociological findings within the spirit of the National Environmental Protection Act of 1969.

LITERATURE CITED

COUNCIL ON ENVIRONMENTAL QUALITY. 1973. Guidelines: Appendix II, Preparation of Environmental Impact Statements (38 F.R. 20550, 1 August).

————. 1974. Environmental Quality—Fifth Annual Report. U.S. Gov't. Print. Off., Washington, D.C.

————. 1975. 102 Monitor, 5(5) June. U.S. Gov't. Print. Off., Washington, D.C.

U.S. ARMY CORPS OF ENGINEERS. 1974. Preparation/Coordination E.I.S.'s. Dept. Army, Off. Chief Engin., Washington, D.C.

————. 1975. Draft Environmental Impact Statement: Clark Maritime Centre, Jeffersonville, Clark County, Indiana, Ohio River Mile 597. Louisville District, Louisville, Ky.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 60–73

Age, Growth, Condition, and Maturity of Sunfishes of Doe Run, Meade County, Kentucky[1]

Walter L. Redmon[2] and Louis A. Krumholz
Department of Biology, University of Louisville,
Louisville, Kentucky 40208

Abstract

Measurements of 1,545 sunfish referable to 9 species indicated that rock bass, longear sunfish, green sunfish, bluegills, smallmouth bass, and spotted bass maintained successful populations in Doe Run. Rates of growth of rock bass, longear sunfish, and bluegills were equal to or greater than in other streams reported in the literature, while those of smallmouth bass, spotted bass, and green sunfish were slightly less. Largemouth bass and white crappies grew very slowly, probably because environmental conditions in Doe Run were marginal. Growth rates of male and female green sunfish, bluegills, and rock bass were similar, but male longear sunfish grew faster than females. Male longear sunfish, green sunfish, and rock bass outlived females of those species. Length–weight relationships and coefficients of condition of all species except rock bass were comparable to those of other streams. All sunfishes that spawned in Doe Run did so only in the lower reaches of the stream in late summer, probably because of the influence of constantly cool water temperatures at the stream source. The longear sunfish–rock bass–smallmouth bass was the most successful sunfish association.

Introduction

Although sunfishes (Centrarchidae) are widely distributed over the eastern United States and include several species very popular among sport fishermen, relatively little is known of their rates of growth in streams. This study presents data for 9 species of centrarchids from Doe Run, Meade County, Kentucky, prior to its impoundment to form Doe Valley Lake in July 1961. Species considered are: rock bass *Ambloplites rupestris*, green sunfish *Lepomis cyanellus*, warmouth *L. gulosus*, bluegill *L. macrochirus*, longear sunfish *L. megalotis*, smallmouth bass *Micropterus dolomieui*, spotted bass *M. punctulatus*, largemouth bass *M. salmoides*, and white crappie *Pomoxis annularis*. Two specimens of each of 2 other sunfishes, the orange-spotted sunfish *L. humilis* and the black crappie *P. nigromaculatus* were collected, but the data were too meager for satisfactory analysis. Nomenclature follows that of Bailey et al. (1970).

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Description of the Study Area

Doe Run, a limestone stream, rises as a torrent spring 4.8 km east and 0.6 km north of Ekron, Kentucky, and flows north-northeast for 15.6 km to empty into the Ohio

[1] Contribution No. 188 (New Series) from the Department of Biology, University of Louisville, Louisville, Kentucky 40208.

[2] Present address: U.S. Environmental Protection Agency, Region V, Chicago, Illinois 60604.

River at Ohio River Mile 642.2, about 57 km downstream from Louisville. Detailed descriptions of the physical and chemical characteristics of the stream have been given by Minckley (1963) and Krumholz (1965, 1967). The portion of the stream sampled during this study did not include the headwaters since no sunfishes maintained populations in that area, but did include the stretch from Highway 1638 (Km 5) to the Ohio River, a distance of 10.8 km (Fig. 1). Within the sampling area, the stream above Km 8 had a gradient of 6.6 m/km, whereas below that point the gradient was 1.7 m/km. Downstream from Km 12.5, the channel was filled with backwater from the pool formed by Ohio River Lock and Dam No. 44 near Leavenworth, Indiana, at an elevation of 374 feet (114 m) above mean sea level (msl). In 1971, Lock and Dam No. 44 was replaced by the Cannelton Locks and Dam at Cannelton, Indiana, and the pool was raised to 383 feet (116.7 m) msl. Thus, the backwater now extends very nearly to the toe of the dam for Doe Valley Lake.

The average width of Doe Run above the backwater was about 10 m, and ranged from more than 12 m in some pools to no more than 2 m at some riffles. Maximum depths in pools was about 2 m, but in many riffles, the water was no more than 20 cm deep. In the area of relatively steep gradient, the bottom was largely a mixture of bedrock, marl, and rubble. Downstream from Km 8, the bottom was mostly silt, sand, and clay with some stones that had washed in during spates.

Prior to 1961, when the lower portion of the valley was cleared, Doe Run flowed for most of its length under a heavy canopy of riparian vegetation. The roots of many large trees had been undercut by the stream and those areas provided shelter for many sunfishes and other species as well.

Water temperatures in Doe Run manifested the moderating effects of groundwater temperatures as well as ambient air temperatures. At the spring source, the temperature rarely varied from 13.3 C. About 5 km downstream, the maximum

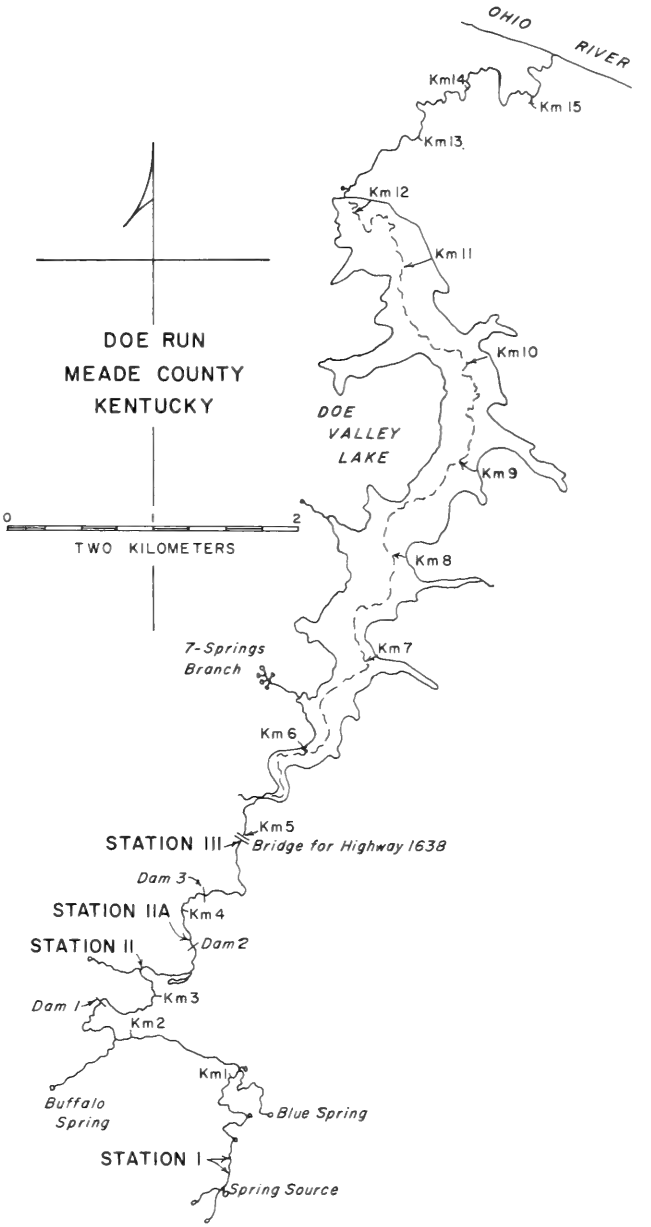

FIG. 1. Map of Doe Run, Meade County, Kentucky, showing stream kilometers, locations of dams, bridge for Highway 1638, and extent of Doe Valley Lake. The broken line through Doe Valley Lake shows the course of the stream prior to impoundment (after Krumholz 1967).

water temperature recorded by Minckley (1963) was 20.0 C in August 1960 and the minimum was 6.1 C in March 1961. Another 3 km downstream, the maximum was 25.6 C and the minimum was 1.7 C. Dissolved oxygen in Doe Run was near or over saturation at all times, and pH was circumneutral. Discharge at the source ranged from less than 0.1 to about 17 m^3/sec.

MATERIALS AND METHODS

Although fishes in this study were collected by electrofishing, seining, and angling, most were taken with emulsifiable rotenone, 9–11 July 1961. The rotenone was used in an attempt to eradicate all fishes from the section of Doe Run to be impounded as Doe Valley Lake (Fig. 1). That collection is important because of its size, homogeneity of time and locality, and relative nonselectivity of method. Other sunfishes were collected between October 1959 and July 1961.

A total of 1,545 specimens referable to 9 species and 4 genera of sunfishes was used: longear sunfish, 567; bluegill, 536; green sunfish, 199; rock bass, 131; spotted bass, 28; white crappie, 26; smallmouth bass, 24; warmouth, 18; and largemouth bass, 16. All specimens were fixed in 10 percent formalin and stored in 70 percent ethanol, but all measurements were made within 48 hours after collection. Scale samples were taken from just below the lateral line under the spinous dorsal fin, along with data on standard, fork, and total lengths in millimeters, weights in grams, and sex. Only standard lengths were used in our calculations.

Age determinations were made from impressions of scales in strips of cellulose acetate after the procedure of Campbell and Witt (1953) and using an Eberbach scale projector. Three scales from each fish were chosen for impressions, and the annuli on those scales were compared. A single scale was chosen for measuring the annual increments, and growth was calculated for each year of life using the formula:

$$L' = C + S'/S\,(L - C)$$

where L' = computed standard length at time of annulus formation,
L = observed standard length at time of capture,
S' = radius of scale at annulus,
S = radius of scale at time of capture, and
C = correction factor,

with the assumption that body length is proportional to scale growth (Van Oosten 1929, Hile 1936, Whitney and Carlander 1956, and others). The correction factor, C, is the intercept of the curve formed by plotting standard length against scale radius.

The only occurrences of sunfishes above Highway 1638 (Fig. 1) were of occasional green sunfish, bluegills, and an orange-spotted sunfish, all adults, probably displaced from nearby sinkholes. No young-of-the-year sunfishes were found upstream from the bridge despite intensive collecting. Similarly, none of the basses, crappies, or other sunfishes were collected upstream from the bridge.

Each spring, numerous sexually mature green sunfish, bluegills, and longear sunfish became concentrated in a large pool just below the swift-flowing culvert of the highway bridge, but there was no spawning in the area, probably because of the coolness of the water (Minckley 1963). Witt and Marzolf (1954), Swingle and Smith (1950), and others have stated that temperatures above a certain minimum (21.1 C) are required to induce spawning in those sunfishes. Several longear sunfish and bluegills caught from the area were resorbing ova at the time of capture (Minckley 1963).

AGE AND GROWTH

Longear Sunfish

The longear sunfish was the most abundant sunfish in Doe Run prior to the impoundment of Doe Valley Lake. Of the 567 specimens used in this study, 440 (78%) were taken during the rotenone treatment of 9–11 July 1961. The longear sunfish made up 36.7 percent of all sunfishes taken during the study.

The oldest specimens were in Age Group VI and the youngest were in Age Group I; no young of the year were collected. The age composition (Table 1) and the length-frequency distribution (Fig. 2) of the 440 individuals taken with rotenone indicated that three-fourths were more than 3 years old and of a greater length than 70 mm. That population composition corresponds

TABLE 1.—LENGTH-FREQUENCY DISTRIBUTIONS OF 442 LONGEAR SUNFISH OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length (mm)	Age group						Total
	I	II	III	IV	V	VI	
30–39	5						5
40–49	5						5
50–59	10	6					16
60–69	8	18					26
70–79		39	15				54
80–89		20	74	3			97
90–99			62	26			88
100–109			5	61	6		72
110–119				26	22	2	50
120–129				3	16	4	23
130–139					2	2	4
Total	28	83	156	119	46	8	440

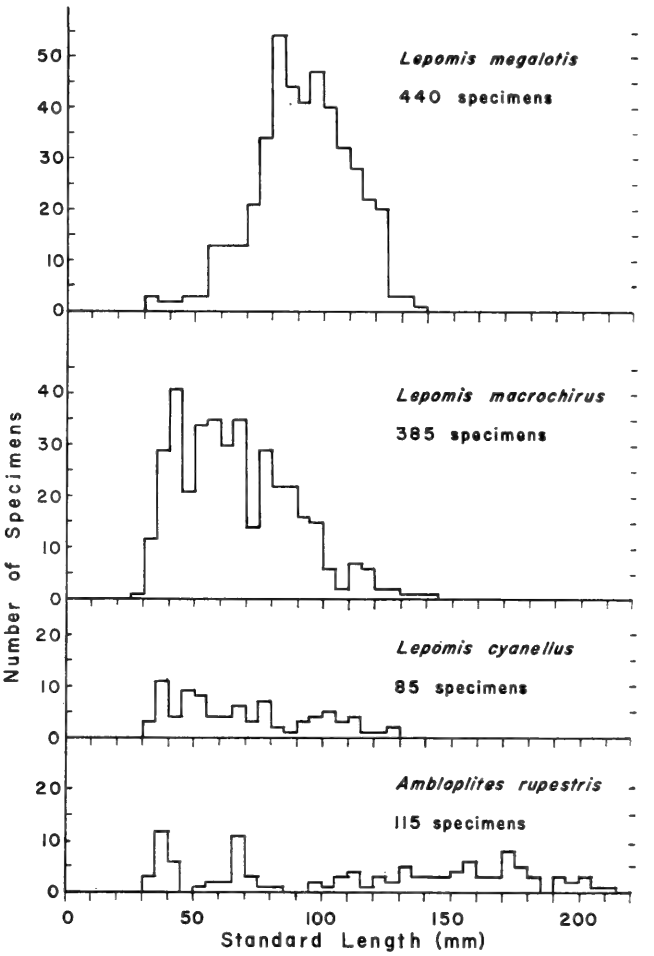

FIG. 2. Length-frequency distributions of the 4 most abundant sunfishes in Doe Run, Meade County, Kentucky, taken during the rotenone treatment 9–11 July 1961.

closely with that reported from the Black River, Missouri (Patriarche and Lowry 1953), but contains a greater percentage of older individuals than reported for Clear Creek, Illinois (Lewis and Elder 1952), and Beaver Creek, Kentucky (Tompkins and Carter 1951).

Calculations of growth rates of 560 individuals, based on a straight-line relationship between body length and length of scale, and corrected for an intercept of 10 mm in body length, showed that longear sunfish reached average lengths of 40, 63, 83, 99, 112, and 119 mm for Age Groups I through VI, respectively (Table 2). The factor for converting standard length to total length is 1.251 based on actual measurements of all longear sunfish taken from Doe Run.

Although female longear sunfish had an average length slightly greater than that of males at the end of the first year's growth (Table 3), males grew faster each succeeding year, and were an average of 8.7 mm longer at the end of the fifth growing season. In Doe Run, male longear sunfish lived longer than females, and the percentage of males in the population increased with increasing age until only males of Age Group VI survived (Table 3). Hubbs and Cooper (1935) also found that male longear sunfish grew faster than females, but made no mention of differences in longevity between the sexes.

The relationship between standard length and weight of longear sunfish in Doe Run was calculated by least squares as:

$$\text{Log } W = -4.80156 + 3.2504 \log L$$

where W = weight of fish in grams and
L = standard length in millimeters.

Lewis and Elder (1952) reported a length–weight relationship for longear sunfish in Clear Creek, Illinois, somewhat lower than that for Doe Run (log W = –4.77 + 3.16 log L). Hile (1931) presented average weights for several groups of longear sunfish in Indiana, but his values were for stunted populations in lakes, and the weights were lower than those for corresponding lengths in Doe Run. Hile (1936)

TABLE 2.—AVERAGE CALCULATED STANDARD LENGTHS IN MILLIMETERS OF SUNFISHES AT THE END OF EACH YEAR OF LIFE, DOE RUN, MEADE COUNTY, KENTUCKY, NOVEMBER 1959 TO JULY 1961

	Calculated length at end of year							
	1	2	3	4	5	6	7	8
Longear sunfish	39.8	63.7	82.5	98.7	111.7	119.4		
Bluegill	35.0	63.4	85.6	105.6	123.7	135.0		
Green sunfish	35.1	62.5	89.6	110.2	127.7			
Rock bass	46.8	76.9	106.9	132.0	155.1	174.0	192.1	206.0
Spotted bass	76.6	126.7	160.8	193.9	228.2	253.0		
Smallmouth bass	77.5	131.5	179.5	224.1	260.1			
Largemouth bass	56.6	102.9	151.0	199.0	227.0			
White crappie	54.5	93.5	114.0					
Warmouth	39.8	64.4	86.7	107.7				

proposed the term "coefficient of condition" as a means of indicating suitability of environment and to provide a measurement by which the fishes of one body of water could be compared with those of another. The average coefficient of condition for longear sunfish in Doe Run was 4.958 as determined from the equation

$$K = 100{,}000\ W/L^3$$

where W = weight of fish in grams and
L = standard length of fish in millimeters.

In their study, Lewis and Elder (1952) reported an average coefficient of condition of 3.56 for 164 longear sunfish from Clear Creek, Illinois, much lower than that for fish from Doe Run.

Of the 402 longear sunfish sexed in this study (Table 3), 95 percent of the females in Age Group II were sexually mature as indicated by enlarged ovaries, whereas only 9 percent of the males in that age group had enlarged testes. In Age Group III, all females were mature, but only 64 percent of the males were in spawning condition. In Age Group IV, all females were sexually mature, but 4 percent of the males were not. The smallest mature female (Age Group I) was 59 mm long and was the only mature individual in the group. The smallest mature male (Age Group II) was 79 mm long and was the only mature male in that group.

Although no young-of-the-year longear sunfish were collected during the study, it is obvious that spawning took place each year. Such successful spawning took place in the large pools and quiet waters in the lower reaches of the stream. It is noteworthy that spawning had not yet occurred by 9 July 1961 when the stream was treated with rotenone.

TABLE 3.—STANDARD LENGTHS IN MILLIMETERS AND NUMBERS OF LONGEAR SUNFISH OF EACH SEX FROM THE 6 AGE GROUPS, DOE RUN, MEADE COUNTY, KENTUCKY, 9–11 JULY 1961, BASED ON 402 INDIVIDUALS. THE FIGURES IN PARENTHESES INDICATE THE NUMBERS OF SPECIMENS

	Age group					
	I	II	III	IV	V	VI
Male	38.3 (162)	63.2 (161)	83.4 (150)	100.3 (113)	111.8 (46)	119.4 (8)
Females	39.1 (240)	62.3 (237)	79.1 (176)	93.4 (59)	104.1 (8)	— —

Bluegill

Among Doe Run sunfishes, the bluegill was second in abundance prior to the rotenone treatment. Of the 536 specimens reported here, 385 (72%) were taken with rotenone, and based on the entire study, the bluegill made up 34.7 percent of all sunfishes in the stream.

Relatively little is known of the growth of bluegills in small streams, but its growth in lentic waters has been studied extensively. The relatively large population of bluegills in Doe Run is believed to be unusual since it is not usually considered a

stream fish. Trautman (1942, 1957) noted that introductions of bluegills into flowing waters in Ohio were unsuccessful, except when some individuals reached oxbows, overflow ponds, or large quiet pools.

The oldest bluegill from Doe Run was a single member of Age Group VI, and members of Age Groups I, II, and III made up more than 95 percent of those taken with rotenone (Table 4). The length-frequency distribution of 385 individuals (Fig. 2) displays the normal pattern of decrease in numbers each succeeding year of age; however, the paucity of larger individuals may suggest a rather unfavorable environment.

Growth rate was calculated for 521 bluegills based on a straight-line relationship between body length and scale length, corrected for an intercept of 9.8 mm in body length. In Doe Run, bluegills attained average lengths of 35, 63, 86, 106, 124, and 135 mm for Age Groups I through VI, respectively (Table 2). The conversion factor for standard to total length is 1.279 based on measurements of all bluegills caught from Doe Run. The growth rate in Doe Run was higher than that reported from other streams except those in Oklahoma studied by Finnell et al. (1956) and Jenkins et al. (1952). The growth rate in Beaver Creek, Kentucky (Tompkins and Carter 1951), was slightly slower the first 2 years, but the small size of their sample makes any comparison questionable. Purkett (1958a) reported that bluegills grew at their fastest rate in the middle portions of streams in Missouri. The habitat in Doe Run is most similar to that described for those streams in Missouri. Growth in the Missouri streams was slower than in Doe Run in the early years of life but may have been faster in the fourth and fifth years.

There was no apparent difference in growth rates of male and female bluegills in Doe Run. The sex ratios through the first 4 years of life was very near 1:1. Of the 7 individuals in Age Group V, 5 were males, and the lone individual in Age Group VI was a male.

All bluegills from Doe Run were used in calculating the length–weight relationship as determined by least squares from the equation $\log W = -5.5035 + 3.5845 \log L$. The curve developed from the equation fitted empirical data from specimens smaller than 100 mm well, but weights of larger individuals were slightly lower.

TABLE 4.—LENGTH-FREQUENCY DISTRIBUTIONS OF 376 BLUEGILLS OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT, 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length	Age group						Total
	I	II	III	IV	V	VI	
20–29	1						1
30–39	39						39
40–49	58						58
50–59	64	2					66
60–69	36	29					65
70–79	1	40	2				43
80–89		18	26				44
90–99		4	27	1			32
100–109			8				8
110–119			4	9			13
120–129				4			4
130–139					2		2
140–149						1	1
Total	199	93	67	14	2	1	376

The coefficient of condition of Doe Run bluegills determined from all specimens, ranged from 2.358 to 5.662 with an average of 3.779.

Sex and gonad conditions were determined for all specimens over 80 mm long in the rotenone sample; smaller specimens were not sexually mature. About half the females in Age Group II larger than 80 mm were mature, but no males that size in that age group had reached maturity. Almost 76 percent of the females in Age Group III were mature, but only 7 percent of the males were mature. At Age Group IV, 86 percent of all fish were mature, and the 3 older specimens, all males, were mature. The smallest mature female was an 80-mm individual of Age Group II, and the smallest mature male (Age Group III) was 93 mm long.

The collection of young-of-the-year bluegills in the lower reaches of Doe Run each year prior to 1961 (Minckley 1963) indicates that the population was permanent,

TABLE 5.—LENGTH DISTRIBUTION OF 82 GREEN SUNFISH OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT, 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length	Age group					Total
	I	II	III	IV	V	
30–39	14					14
40–49	13					13
50–59	12					12
60–69	6	2				8
70–79		10				10
80–89		3				3
90–99			5	1		6
100–109			5	3		8
110–119			1	4		5
120–129				2	1	3
Total	45	15	11	10	1	82

and not maintained through ingress from the Ohio River.

Green Sunfish

The green sunfish was the third most abundant sunfish in Doe Run prior to the impoundment of Doe Valley Lake; it made up 12.9 percent of all sunfishes taken from Doe Run. Of the 199 specimens collected during the study, only 85 (43%) were taken in the rotenone sample. The rotenone sample contained a single specimen of Age Group V, the oldest, a male, and more than half the sample was made up of members of Age Group I (Table 5). The length-frequency distribution is representative of the population during the summer of 1961.

Growth rate was calculated for 186 individuals based on a straight-line relationship between body length and scale length, and corrected for an intercept of 9.6 mm. Average standard lengths for Age Groups I through V, respectively, were 35, 63, 90, 110, and 128 mm (Table 2). The conversion factor for standard to total length is 1.254 based on measurements of all green sunfish in the Doe Run collection. The growth rate in Doe Run was below average for many streams cited in the literature. In 6 Missouri streams, green sunfish from only the St. Francis and Gasconade rivers grew more slowly than those in Doe Run (Purkett 1958a, 1958b; Patriarche and Lowry 1953). In Oklahoma, green sunfish in the Little River and Illinois River systems attained average lengths by the end of 3 years that exceeded average lengths of individuals of Age Group V in Doe Run (Finnell et al. 1956, Jenkins et al. 1952).

Little difference was noted in the growth rates of male and female green sunfish in Doe Run. Hubbs and Cooper (1935) noted that the growth rate for male green sunfish in Michigan was considerably greater than that of females.

In Doe Run, males lived longer than females, and the percentage of males in the population increased with age until Age Group V when only males survived.

Length–weight relationships were determined for all green sunfish from Doe Run by least squares with the equation $\log W = -4.7064 + 3.1376 \log L$. The curve developed from that equation fitted empirical data for all specimens. Lewis and Elder (1952) reported a length–weight relationship for green sunfish in Clear Creek, Illinois, as best represented by the equation $\log W = -4.89 + 3.19 \log L$, an indication that Clear Creek individuals were lighter than their Doe Run counterparts.

The average coefficient of condition of 197 green sunfish from Doe Run was 3.520, ranging from 2.700 to 4.912. Lewis and Elder (1952) reported a mean coefficient of condition of 3.19 for 83 individuals that ranged from 55 to 199 mm in standard length. Those data indicate that conditions in Doe Run were better than in Clear Creek, at least for green sunfish.

Sex and condition of gonads were determined for all green sunfish longer than 60 mm from the rotenone sample. Two of the large females but none of the males in Age Group I were sexually mature. About a third of the males and 70 percent of the females in Age Group II had reached maturity. All individuals of older age groups were mature. The smallest mature females were 2 67-mm individuals of Age Group I; the smallest mature male was a 76-mm specimen of Age Group II.

More small green sunfish than young of

TABLE 6.—LENGTH-FREQUENCY DISTRIBUTION OF 106 ROCK BASS OF ALL AGE GROUPS TAKEN DURING THE ROTENONE TREATMENT, 9–11 JULY 1961, DOE RUN, MEADE COUNTY, KENTUCKY

Standard length	Age group I	II	III	IV	V	VI	VII	VIII	Total
30–39	13								13
40–49	5								5
50–59	3								3
60–69	2	10							12
70–79	1	2							3
80–89		1							1
90–99		1	1						2
100–109		3	1						4
110–119		2	1	1					4
120–129			2	2	1				5
130–139			1	6	1				8
140–149				3	4				7
150–159					9	1			10
160–169					6				6
170–179					3	8			11
180–189					1	2			3
190–199							4		4
200–209						1	3		4
210–219								1	1
Total	24	19	6	12	25	12	7	1	106

any other sunfish were taken in the downstream area of Doe Run, indicating that reproduction was common in pools of that area. Minckley (1963) reported that green sunfish reproduced in Doe Valley Lake shortly after its impoundment, indicating that the species had survived the attempted eradication with rotenone.

Rock Bass

The rock bass, the fourth most abundant sunfish in Doe Run, was commonly found among the undercut roots of riparian sycamore trees *Platanus occidentalis* L. A total of 131 specimens was taken during the entire study and they made up 8.5 percent of all sunfishes. The rotenone study yielded 115 specimens. The number of large individuals made the population of interest to the angler, but there was little utilization of the fishery. The length-frequency distribution of all specimens from Doe Run is shown in Fig. 2.

The oldest rock bass in the collection was of Age Group VIII, and young of the year were collected 2–6 km downstream from the bridge for Highway 1638 in the fall of 1960. The age composition of 106 specimens from the rotenone study is shown in Table 6.

Rate of growth was calculated for 121 rock bass based on a straight-line relationship between body length and scale length and corrected for an intercept of 18.3 mm. In Doe Run, the respective standard lengths for Age Groups I through VIII were 47, 77, 107, 132, 155, 174, 192, and 206 mm (Table 2). The conversion factor for standard to total length is 1.226 based on measurements of all rock bass. The rate of growth in Doe Run, although faster during the first year, was similar to that reported for the middle sections of Missouri streams by Purkett (1958a) and the Tippecanoe River, Indiana, by Scott (1949). The growth rate in Doe Run was greater than that reported for the Black River, Missouri, by Patriarche and Lowry (1953). Growth rates of rock bass from 2 Kentucky streams reported by Tompkins and Carter (1951) were much greater than in Doe Run, or any other stream for that matter, but their samples were small. In the Illinois River system

of Oklahoma (Jenkins et al. 1952), the growth rate was higher than in Doe Run.

No significant difference in growth rates of males and females was apparent in Doe Run. Still, based on the fish taken with rotenone, males outlived females. Of the specimens sexed, 62 percent of those in Age Groups II, III, and IV were females, but only 27 percent of those in Age Groups V through VIII were females. Only 1 of 7 specimens in Age Group VII was a female, and the lone fish in Age Group VIII was a male. Hile (1941) reported that the growth rate of male rock bass in Nebish Lake, Wisconsin, exceeded that of females, but that females lived longer than males.

All specimens in the Doe Run collection were used to calculate the length–weight relationship. The equation determined by least squares was log W = –4.4625 + 3.0329 log L. The curve derived from that equation fitted empirical data for all sizes. Scott (1949) determined the length–weight relationship for rock bass in the Tippecanoe River to be log W = –5.040 + 2.908 log L. Comparison of values from those curves indicates that fish from Doe Run were relatively lighter than those from the Tippecanoe River.

Most adult rock bass from Doe Run in July 1961 were not at peak sexual maturity, indicating that reproduction had not yet taken place. Young-of-the-year rock bass taken in the fall of 1960 were no longer than 24 mm standard length in September or December, a strong indication of very late spawning dates. Rock bass spawned throughout the lower reaches of Doe Run. The smallest sexually mature female was a 105-mm specimen of Age Group II, and the smallest mature male was a 110-mm individual of the same age.

Spotted Bass

Spotted bass were collected more often than either of the other black basses, but only 2 of the 28 specimens in our sample were taken with rotenone. Based on all collections, it made up 1.8 percent of the total sunfish population. The oldest specimens belonged to Age Group VI, and 4 young of the year were the youngest, and averaged 31 mm standard length.

Growth rates were determined for 24 individuals based on a straight-line relationship between body length and scale length and corrected for an intercept of 27.4 mm. That intercept is the average value reported by Bryan (1964, unpublished doctoral dissertation, University of Louisville, Louisville, Kentucky) for all his stations. In Doe Run, spotted bass attained average lengths of 77, 127, 161, 194, 228, and 253 mm for Age Groups I through VI, respectively (Table 2). The conversion factor for standard to total length is 1.225 based on measurements of all Doe Run specimens.

The growth rate of spotted bass in Doe Run was lower than that for streams in Missouri (Purkett 1958a), Oklahoma (Jenkins et al. 1952, Finnell et al. 1956), or from Slate Creek, Kentucky (Tompkins and Carter 1951). Bryan (unpublished dissertation) compared growth rates throughout its range in streams and impoundments and found no trends attributable to geography, but instead believed that local factors in the habitat were responsible for any variations.

Length–weight relationship for spotted bass from Doe Run was calculated using the equation log W = –4.9287 + 3.1778 log L. Such a relationship for spotted bass in several streams in the Ohio River valley (Bryan unpublished dissertation) was best represented by log W = –5.138 + 3.124 log L. Weight values derived from that curve are slightly lower than corresponding values from Doe Run.

The average coefficient of condition of the 28 individuals from Doe Run was 2.532 and ranged from 1.707 to 3.237. Lewis and Elder (1953) reported an average value of 2.46 for Clear Creek, Illinois, and Bryan (unpublished dissertation) reported average values that ranged from 2.27 to 2.90 for 8 stream populations. Comparison of those data indicates that spotted bass from Doe Run were in slightly better condition than the averages for the other streams.

Young-of-the-year specimens from the

lower reaches of Doe Run in September and October 1960 showed that reproduction had been successful. Large adults taken during the rotenone study had not yet reached spawning condition, but their gonads were approaching that stage. It appears that the spotted bass maintained a small permanent population in the large pools near the lower end of Doe Run.

Smallmouth Bass

The smallmouth bass was rare in Doe Run and its distribution was restricted to the lower reaches of the stream. A total of 24 specimens was taken, 14 of which were caught in the rotenone treatment. Based on all collections, it made up 1.5 percent of all sunfishes in Doe Run. Tate (1949) reported as many as 100 adult smallmouth bass ("a dense population") in a 4-km stretch of Coffin Creek, Iowa.

The oldest individuals in Doe Run were in Age Group V, and young of the year were taken in 1960 and 1961. The single 15-mm young-of-the-year smallmouth bass taken during the rotenone study was the only sunfish of that age group taken during 1961. Large specimens of Age Groups IV and V made up two-thirds of all smallmouth bass, an indication that the population, like those of other sunfishes, was underexploited. Minckley (1963) reported seeing an angler with a smallmouth bass from Doe Run that weighed 964 g after viscera and scales had been removed. That individual was considerably larger than any in the Doe Run collection. That small number in the collection precludes any satisfactory length-frequency distribution.

Growth rates were calculated for 20 individuals based on a straight-line relationship between body length and scale length and corrected for an intercept of 14.6 as determined by Everhart (1950). No body–scale relationship was attempted from Doe Run data. Smallmouth bass in Doe Run attained lengths of 78, 132, 180, 224, and 260 mm, respectively, at ages I through V (Table 2). In addition, 3 individuals of Age Group O, collected in mid-August 1960, averaged 33 mm standard length, and a 15-mm specimen was taken during the rotenone study. The conversion factor for standard to total length is 1.216 based on measurements of all Doe Run specimens.

Growth rate of smallmouth bass in Doe Run was slightly below average for some streams in Missouri (Purkett 1958a, Patriarche and Lowry 1953) and Oklahoma (Jenkins et al. 1952, Finnell et al. 1956), but was much greater than that reported by Suttkus (1955) for Fall Creek, New York, and somewhat higher than that in Coffin Creek, Iowa (Tate 1949). The growth rate in Elkhorn Creek, Kentucky (Tompkins and Carter 1951), one of the best-known smallmouth bass streams in the state, was much higher than that reported for any other stream.

Measurements of all specimens from Doe Run were used to calculate length–weight relationship. The equation, as determined by least squares, was $\log W = -6.011 + 3.586 \log L$. Tate (1949) reported that relationship as $\log W = -4.8128 + 3.0935 \log L$ for smallmouth bass in Coffin Creek, Iowa, indicating that they were heavier than those from Doe Run. Populations in Missouri Ozark streams (Purkett 1958a) and Fall Creek, New York (Suttkus 1955), also had length–weight relationships greater than that in Doe Run.

The average coefficient of condition of Doe Run smallmouth bass was 2.425. It was lower than that reported by Tate (1949) for Coffin Creek, Iowa, but higher than that reported by Suttkus (1955) for Fall Creek, New York. The high coefficient of condition for smallmouth bass in Doe Run indicates that the environment is favorable for the species.

Largemouth Bass

The largemouth bass was rare in Doe Run, and its distribution was limited to the large pools in the lower reaches of the stream; still, an individual was collected near the bridge for Highway 1638 in June 1961. Only 16 individuals were collected from Doe Run, and 14 of those were in the

rotenone collection. Based on all collections, the largemouth bass made up 1.0 percent of the total sunfish population in Doe Run.

The oldest individual was of Age Group V and the youngest were in Age Group I. No young of the year were taken. More than half the specimens in all collections were of Age Group II (Table 2). The growth rate was calculated for 15 individuals based on a straight-line relationship between body length and scale length corrected for an intercept of 25.4 mm. The largemouth bass in Doe Run had attained average lengths of 57, 103, 151, 199, and 227 mm for Age Groups I through V, respectively (Table 2). The conversion factor for standard to total length is 1.227 based on measurements of all specimens.

The growth rate for largemouth bass in Doe Run was very slow. They grew more slowly than in any of the streams in Missouri (Purkett 1958a), in Kentucky (Tompkins and Carter 1951), and in Oklahoma (Jenkins et al. 1952, Finnell et al. 1956). In the Clinch River, Tennessee, below Norris Dam, Eschmeyer (1944) reported that age determination of 108 largemouth bass taken after 15 November 1943 revealed that individuals up to 300 mm total length (ca. 245 mm standard length) were young of the year, none having annuli on their scales.

Measurements of all largemouth bass from Doe Run were used to calculate the length–weight relationship from the equation $\log W = -4.839 + 3.106 \log L$. The average coefficient of condition for those fish was 2.451. Eschmeyer (1944) reported a coefficient of condition of 2.19 for largemouth bass from the Clinch River. Thus, that species in Doe Run was plumper than most other stream populations even though they grew very slowly.

None of the largemouth bass from Doe Run was in breeding condition in July 1961. One female contained eggs in an early stage of development.

White Crappie

The white crappie was not collected from Doe Run until 1961 when it was taken from the backwater of the Ohio River. The 26 specimens taken during the entire study period made up 1.7 percent of the total sunfish population. All specimens were small, the largest being an individual of Age Group III; the youngest were 5 individuals of Age Group I. No young of the year were collected.

Growth rate was calculated for the 20 specimens taken with rotenone based on a straight-line relationship between body length and scale length. Those fish had attained average standard lengths of 71, 123, and 150 mm at ages I through III, respectively (Table 2). The conversion factor for standard to total length is 1.213 based on measurements of all specimens. The growth rate in Doe Run was below the average for white crappies from Slate Creek, Kentucky (Tompkins and Carter 1951), the St. Francis River, Missouri (Purkett 1958a), and Poteau River, Oklahoma (Hall 1951), but was greater than in the Salt, Gasconade, and Meramec rivers, Missouri (Purkett 1958a, 1958b), and the Little and Illinois rivers, Oklahoma (Jenkins et al. 1952, Finnell et al. 1956).

All specimens from Doe Run were used to calculate the length–weight relationship from the equation $\log W = -6.1946 + 3.7658 \log L$. The average value was 2.382. Hansen (1951) reported seasonal changes in coefficient of condition among male and female white crappies from Lake Decatur, Illinois, with values for males being higher than for females.

Warmouth

Prior to the rotenone treatment, only a single warmouth had been collected from Doe Run. The rotenone study produced an additional 17 specimens. Those fish were limited to the sluggish pools in the lower reaches of the stream. Based on all data, the warmouth made up 1.2 percent of the total sunfish population.

The oldest individuals were in Age Group IV, and 2 individuals of Age Group I were the youngest. Growth rate was calculated for 18 specimens based on a straight-line

relationship between body length and scale length corrected for an intercept of 13.4 mm. The average standard lengths were 40, 64, 87, and 108 mm, respectively, for Age Groups I through IV. The conversion factor for standard to total length is 1.240 based on measurements of all specimens.

The growth rate (Table 2) was slower than that reported by Tompkins and Carter (1951) from Slate Creek, Kentucky, by Finnell et al. (1956) and Jenkins et al. (1952) for the Little and Illinois river systems, Oklahoma, and from the Mississippi River (Upper Mississippi Conservation Commission 1946). Also, it was much slower than that reported for 2 Illinois lakes by Larimore (1957).

The length–weight relationship was based on all specimens using the equation log W = –5.359 + 3.504 log L. The average coefficient of condition for warmouths in Doe Run was 4.089.

Discussion and Conclusions

Eleven centrarchids were present in Doe Run prior to the rotenone treatment of 9–11 July 1961, when most fishes used in this study were collected. Of those, 9 were present in sufficient numbers for analysis of growth rate, coefficient of condition, age at maturity, and length-frequency distribution. Except for a few isolated individuals, all sunfishes were restricted to the area downstream from the bridge for Highway 1638 (Fig. 1) by a combination of factors including obstruction of stream flow, high gradient, water temperature, and lack of suitable habitat. Lack of sufficient cover and competition with other species more suited to Doe Run's environment played a major role in limiting the sunfish population.

Populations of rock bass, longear sunfish, smallmouth bass, and spotted bass contained majorities of older individuals, indicating that the populations were mature and underexploited. The populations of bluegills and green sunfish contained relatively large numbers of young individuals, indicating reproductive success. Collectively, all other sunfishes made up less than 5 percent of the total sunfish population, and none was known to have reproduced in Doe Run, although the warmouth and the largemouth bass may have done so on occasion.

The growth rates of different sunfishes are indications of the suitability of the environment. The most abundant sunfish in Doe Run, the longear sunfish, grew faster than the average rate of other streams reported in the literature. The bluegills also grew faster than those reported from other streams, but not as fast as in lakes. The rock bass, abundant in a limited area of Doe Run, had an average growth rate comparable with that of other streams; that population contained many individuals larger than average for most Kentucky streams. The growth rates of smallmouth bass, spotted bass, and green sunfish were slightly less than those reported for other streams. However, the smallmouth bass grew faster than they did in streams of comparable size reported in the literature, Fall Creek, New York (Suttkus 1955), and Coffin Creek, Iowa (Tate 1949). Other centrarchids in Doe Run, the largemouth bass, warmouth, and white crappie grew very slowly when compared with those from other streams, indicating that environmental conditions in Doe Run probably were marginal; those species refer warmer and more sluggish or lentic waters.

Growth rates of male and female green sunfish, bluegill, and rock bass were similar, but the male longear sunfish grew noticeably faster than females. Also, males of those 4 species lived longer than females. Females of all species considered reached sexual maturity at younger ages than males.

Analyses of length–weight relationships indicated that only the rock bass was below those reported for other streams. Comparisons were hindered by the paucity of suitable material from other streams. Bennett (1938) reported that slower growing populations of smallmouth bass in Wisconsin lakes had relatively higher average weights than fast growing individuals. However, Tate (1949) found that smallmouth bass in

Coffin Creek, Iowa, that had a faster growth rate than reported by Bennett, were also heavier. It appeared that any attempt to relate length–weight relationships with growth rates may be misleading. Although the growth rates of the different species of sunfishes in Doe Run ranged from above average to below average, all species except the rock bass and white crappie were heavier than average. Within geographic regions, the relative weights of sunfishes are controlled by the food available and not solely on increase in length after embryological development. While growth can be controlled by several factors, temperature of the water and length of the growing season play dominant roles (Bennett 1938, Thompson 1941).

Of the sunfishes collected during the rotenone treatment of 9–11 July 1961, only the smallmouth bass was known to have spawned already that year. Some female longear sunfish appeared to be in peak spawning condition, as indicated by the condition of the ovaries, but no spent females were found. Other species did not appear ready to spawn. Those data indicate that spawning dates for sunfishes in Doe Run are relatively late in the year probably because of the constant coolness of the water at the source of the stream and the almost complete shading of the stream by riparian trees and their influence on water temperatures downstream.

From the information at hand, the most successful association of centrarchids in Doe Run is the longear sunfish–rock bass–smallmouth bass. Based on our collections elsewhere, that association is not uncommon for cool, clear, free-flowing, gravel-bottomed streams.

LITERATURE CITED

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. No. 6:1–149.

BENNETT, G. W. 1938. Growth of the smallmouthed black bass, *Micropterus dolomieu* Lacépède, in Wisconsin waters. Copeia 1938 (4):157–170.

CAMPBELL, R. S., AND A. WITT, JR. 1953. Impressions of fish scales in plastic. J. Wildl. Manage. 17(2):218–219.

ESCHMEYER, R. W. 1944. Fish migration into the Clinch River below Norris Dam, Tennessee. J. Tenn. Acad. Sci. 19(1):31–41.

EVERHART, W. H. 1950. Relation between body length and scale measurements in the smallmouth bass. J. Wildl. Manage. 14(3):266–276.

FINNELL, J. C., R. M. JENKINS, AND G. E. HALL. 1956. The fishery resources of the Little River system, McCurtain County, Oklahoma. Rept. Okla. Fish. Res. Lab. 55:1–82.

HALL, G. E. 1951. Preimpoundment fish populations of the Wister Reservoir area in the Poteau River basin, Oklahoma. Trans. N. Amer. Wildl. Conf. 16:266–283.

HANSEN, D. F. 1951. Biology of the white crappie in Illinois. Bull. Ill. Nat. Hist. Surv. 25 (4):207–265.

HILE, R. O. 1931. The growth of fishes in Indiana. Invest. Ind. Lake Streams 1(2):9–55.

———. 1936. Age determination of fish from scales: method and application to fish cultural problems. Prog. Fish-Cult. 23:1–5.

———. 1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts, Lett. 33:189–337.

HUBBS, C. L., AND G. P. COOPER. 1935. Age and growth of the longeared and green sunfishes in Michigan. Pap. Mich. Acad. Sci., Arts Lett. 20:669–696.

JENKINS, R. M., E. M. LEONARD, AND G. E. HALL. 1952. An investigation of the Illinois River and preimpoundment of Tenkiller Reservoir, Oklahoma. Rept. Okla. Fish. Res. Lab. 26: 1–136.

KRUMHOLZ, L. A. 1965. A radioecological study of the biota of Doe Run, Meade County, Kentucky. U.S. Atomic Energy Comm. Doc. No. TID-22815.

———. 1967. Accumulation of radioactive fallout materials in the biota of Doe Run, Meade County, Kentucky, 1959–1963. Pp. 791–818. *In* Radioecological Concentration Processes. Pergamon Press, New York, N.Y. 1040 pp.

LARIMORE, R. W. 1957. Ecological life history of the warmouth (Centrarchidae). Bull. Ill. Nat. Hist. Surv. 27:1–83.

LEWIS, W. M., AND D. ELDER. 1952. The fish population of the headwaters of a spotted bass stream in southern Illinois. Trans. Amer. Fish. Soc. 82:193–202.

MINCKLEY, W. L. 1963. The ecology of a spring stream Doe Run, Meade County, Kentucky. Wildl. Monogr. 11:1–124.

PATRIARCHE, M. E., AND E. M. LOWRY. 1953. Age and growth of five species of fish in Black

River, Missouri. Univ. Mo. Stud. 26(2):85–109.

PURKETT, C. A., JR. 1958a. Growth rates of Missouri stream fishes. Dingell-Johnson Program. Publ. Mo. Cons. Comm. 1:1–46.

————. 1958b. Growth of fishes in the Salt River, Missouri. Trans. Amer. Fish. Soc. 87 (1957):116–131.

SCOTT, D. C. 1949. A study of a stream population of rock bass, *Ambloplites rupestris*. Invest. Ind. Lakes Streams 3(3):169–234.

SUTTKUS, R. D. 1955. Age and growth of a small stream population of "stunted" smallmouth bass, *Micropterus dolomieu dolomieu* (Lacépède). N.Y. Fish Game J. 2(1):83–94.

SWINGLE, H. S., AND E. V. SMITH. 1950. Factors affecting the reproduction of bluegill bream and largemouth bass in ponds. Agric. Exp. Sta., Ala. Poly. Inst. Circ. 87:1–8.

TATE, W. H. 1949. Growth and food habits of smallmouth black bass in some Iowa streams. Ia. St. Coll. J. Sci. 23(4):343–354.

THOMPSON, D. H. 1941. The fish production of inland streams and lakes. Pp. 206–217. *In* A symposium on hydrobiology. Univ. Wis. Press, Madison, Wis. 405 pp.

TOMPKINS, W. A., AND B. T. CARTER. 1951. Growth rates of some Kentucky fishes. Fish. Bull., Ky. Cons. Comm. 6:1–9.

TRAUTMAN, M. B. 1942. Fish distribution and abundance correlated with stream gradients as a consideration in stocking programs. Trans. N. Amer. Wildl. Conf. 7:211–223.

————. 1957. The fishes of Ohio. Ohio St. Univ. Press, Columbus, O. 683 pp.

UPPER MISSISSIPPI CONSERVATION COMMISSION. 1946. Second progress report of the technical committee for fisheries. 27 pp.

VAN OOSTEN, J. 1929. Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. Bur. Fish. 44: 263–428.

WHITNEY, R. R., AND K. D. CARLANDER. 1956. Interpretation of body–scale regression for computing body length of fish. J. Wildl. Manage. 20(1):21–27.

WITT, A., JR., AND R. C. MARZOLF. 1954. Spawning and behavior of the longear sunfish, *Lepomis megalotis megalotis*. Copeia 1954 (3):188–190.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 74–75

On the Occurrence of the Cedar Glade Endemic *Viola egglestonii* in Kentucky

Jerry M. Baskin and Carol C. Baskin
School of Biological Sciences, University of Kentucky,
Lexington, Kentucky 40506

Abstract

Viola egglestonii Brainerd, previously known to occur only in Bullitt County in Kentucky, is reported from 3 localities in Nelson County. A 1977 publication reporting the species as "common" in Hart County and "abundant" in Warren County is repudiated.

Viola egglestonii Brainerd (Violaceae) is a perennial, stemless blue violet endemic to cedar (limestone) glades of the southeastern United States. Its center of distribution is in the Central Basin of Tennessee, but disjunct populations occur on cedar glades in Alabama, Georgia, and Kentucky. In Kentucky, the species was known only from Bullitt County in north-central Kentucky, where it occurs on cedar glades developed on Silurian limestone (Baskin and Baskin 1975a, Baskin and Baskin 1975b).

We have discovered 3 other populations of *V. egglestonii* on small cedar glades in Nelson County: (1) along old US Highway 31E, 0.8 miles (1.3 km) south of State Highway 46 east of Balltown (J. and C. Baskin #1797, 12 September 1976, KY, VDB), (2) along Jim Clark Rd., 0.2 miles (0.3 km) west of State Highway 46 east of Balltown (J. and C. Baskin #1922, 19 May 1977, KY, VDB), and (3) along Nat Rogers Road (State Highway 46), 1.5 miles (2.4 km) west of US 31E (J. and C. Baskin #1913, 19 May 1977, KY, VDB). Those localities are approximately 20 miles (32 km) south of the nearest population of *V. egglestonii* in Bullitt County. The Nelson County cedar glades on which *V. egglestonii* grows also are on Silurian limestone.

Characteristic cedar glade species growing with *V. egglestonii* in Nelson County include *Agave virginica* L., *Asclepias verticillata* L., *Croton capitatus* Michx., *C. monanthogynus* Michx., *Desmanthus illinoensis* (Michx.) MacM., *Euphorbia corollata* L., *Houstonia canadensis* Willd., *H. nigricans* (Lam.) Fern., *Hypericum dolabriforme* Vent., *Isanthus brachiatus* (L.) BSP, *Nothoscordum bivalve* (L.) Britt., *Panicum flexile* (Gattinger) Scribn., *Rosa carolina* L., *Ruellia humilis* Nutt., *Scutellaria parvula* Michx., *Sisyrinchium albidum* Raf., and *Sporobolus vaginiflorus* (Torr.) Wood. Nomenclature follows Fernald 1950. The blue-green alga *Nostoc commune* Vauch. also is present.

In a compilation entitled "Endangered Plants and Animals of Kentucky," Babcock (1977) showed, on a county map of Kentucky, *V. egglestonii* occurring in Bullitt, Hart, and Warren counties. Furthermore, he indicated that *V. egglestonii* is "common" in Bullitt and Hart counties and "abundant" in Warren County. In Bullitt County, we have located about a dozen populations of *V. egglestonii* in the eastern portion of the county. For the most part, those populations are small, often with less than 100 plants scattered over an area of only a few square meters. Although there are a few small cedar glades in Hart and Warren counties, we have never found *V. egglestonii* on any of them. The only mention in the literature of the occurrence of the species in Warren County is in a report entitled "Violets of North America" by Ezra Brainerd in 1921. In that report, Brainerd mentioned a single specimen of *V. egglestonii* collected by Miss Sadie F. Price from near Bowling Green on 11 April 1899. According to Brainerd, that specimen was at the St. Louis Botanical Garden, and it was labeled *V. falcata* Greene. We have corresponded with Dr. Marshall Crosby of the St. Louis Botanical Garden about the Sadie Price specimen. In a letter to J.

Baskin dated 13 June 1977, Dr. Crosby stated that, "I have been unable to locate this specimen filed either under *V. egglestonii* or *V. falcata.*" Thus, there is no specimen to verify that *V. egglestonii* has ever been collected in Warren County.

The only report of the occurrence of *V. egglestonii* in Hart County is by Braun (1943) in her catalogue of spermatophytes of Kentucky. Dr. Braun reported a single collection of the species from Hart County. The specimen is now deposited in the U.S. National Herbarium, bearing a label with the following information: E. Lucy Braun No. 3910 "on dry sw slope, open red cedar "Big Woods" in Hart County, Ky., May 2, 1941." We have carefully examined the specimen, and it definitely is not *V. egglestonii.* We were unable to identify the species, but it appears to be either *V. esculenta* Ell. or *V. triloba* Schwein. var. *triloba.* The lobing of the leaves and the sparse pubescence on the leaf surfaces are characteristic of *V. esculenta,* a species not known to occur in Kentucky. The specimen has leaf lobing characteristic of *V. triloba* var. *triloba,* and it was collected within the range of that species. However, the leaves on the specimen are not very pubescent as they are in good *V. triloba* var. *triloba* (Brainerd 1921, Russell 1965). Thus, there is no specimen to verify the occurrence of *V. egglestonii* in Hart County.

In summary, *Viola egglestonii* in Kentucky appears to be restricted to a few small populations on cedar glades in Bullitt and Nelson counties.

Literature Cited

Babcock, J. V. 1977. Endangered plants and animals in Kentucky. A publication of the Office of Research and Engineering Services. College of Engineering, University of Kentucky. Lexington, Ky. 128 pp.

Baskin, C. C., and J. M. Baskin. 1975a. The cedar glade flora of Bullitt County, Kentucky. Castanea 40:184–190.

Baskin, J. M., and C. C. Baskin. 1975b. Geographical distribution of the cedar glade endemic *Viola egglestonii.* Rhodora 77:427–429.

Brainerd, E. 1921. Violets of North America. Vt. Agric. Exp. Sta. Bull. 224. 172 pp.

Braun, E. L. 1943. An annotated catalogue of spermatophytes of Kentucky. Published by the author, Cincinnati, Ohio. 161 pp.

Fernald, M. L. 1950. Gray's manual of botany. 8th Ed. Amer. Book Co., New York, N.Y. 1632 pp.

Russell, N. H. 1965. Violets (*Viola*) of central and eastern United States. Sida 2:1–113.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 76–77

An Infrequently Reported Alga: *Chadefaudiothrix gallica* Bourrelly (Xanthophyceae:Heterotrichales)[1,2]

GARY E. DILLARD
Department of Biology, Western Kentucky University,
Bowling Green, Kentucky 42101

ABSTRACT

Chadefaudiothrix gallica Bourrelly, an infrequently encountered xanthophyte, is reported from south-central Kentucky representing its second known locale in addition to the type locale in France. The major distinguishing characteristics and known distribution of the 3 described species of the genus are summarized.

The xanthophycean genus *Chadefaudiothrix* was erected by Bourrelly (1957). The type species, *C. gallica*, was collected from an acidic pond (pH 6.5) in France. Two additional species, *C. fluitans* (Fritsch) Bourrelly [= *Ecballocystis fluitans* Fritsch, 1933] and *C. minouchetii* (Bourrelly) Bourrelly [= *Elakatothrix minouchetii* Bourrelly, 1947], were recognized by Bourrelly (1957). Distinguishing characteristics and known distributions of the 3 species are summarized in Table 1.

The genus is characterized by forming gelatinous tubes that are simple or anastomosed and uni- or multiseriate. Individual cells, that may not be contiguous with their neighbors within the tube, are secondarily enclosed by a sheath clearly distinguishable from that of the primary tube. The tubes are free or may be attached by a gelatinous holdfast to the substrate. The cells are elongate-cylindrical, rarely slightly reniform, with rounded to slightly truncated apexes. Each cell contains 1–4 parietal chloroplasts without pyrenoids. The only known means of reproduction is accomplished by oblique vegetative cell division.

Apparently, the genus was known only from the type locales in France and England prior to Whitford and Schumacher's (1969) report of *C. gallica* from acidic swamp pools in Wake County, North Carolina.

C. gallica (Fig. 1) was collected from Sloan's Crossing Pond, Mammoth Cave National Park (Edmonson County, Kentucky), in March 1976 (pH 6.2, 12 C). In spite of intensive examination of the samples available at that time, only 3 specimens were found. Although routine collections have been taken from the pond subse-

[1] Dedicated to Dr. Larry Alston Whitford on the occasion of his 75th birthday.

[2] I wish to thank Dr. Pierre Bourrelly for verifying the identification.

TABLE 1.—MAJOR DISTINGUISHING CHARACTERISTICS AND KNOWN DISTRIBUTION OF THE 3 DESCRIBED SPECIES OF *Chadefaudiothrix* BOURRELLY

Species	Number of chloroplasts	Dimensions (μ) Tubes (width)	Dimensions (μ) Cells (width/length)	Habit	Distribution
C. gallica	2	30–35	6–8 × 27–30	anastomosing tubes, metaphytic	France; USA: Ky, NC
C. fluitans	4	14–18	3.0–3.5 × 9–18	anastomosing tubes, metaphytic	England
C. minouchetii	1	13–15	2 × 12–26	simple tubes, epiphytic	France

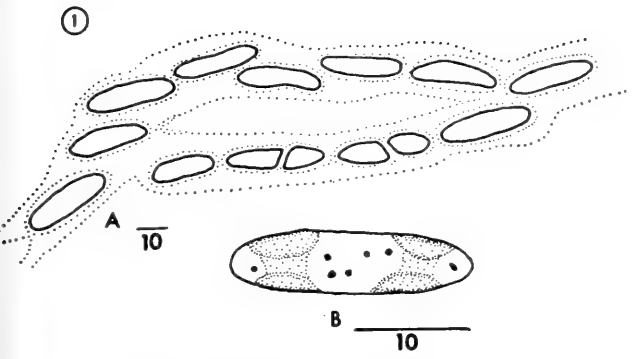

FIG. 1. *Chadefaudiothrix gallica* Bourrelly. A. Portion of anastomosing tube; B. single vegetative cell. Scales in microns.

quently, no additional specimens of *C. gallica* have been observed.

With the exception of reports by Whitford and Schumacher (1969, 1973), Meyer and Brook (1969), and Tarapchak (1972), the xanthophycean flora of the United States is poorly known. It appears that the more ephemeral forms, excluding such genera as *Ophiocytium*, *Tribonema*, and *Vaucheria*, occur primarily in dystrophic ponds, swamps, and bogs with major vegetative development in early spring and fall when water temperatures are 10–15 C.

LITERATURE CITED

BOURRELLY, P. 1947. Algues rares et nouvelles des mares de la Forêt de Fontainebleau. Rev. Gén. Bot. 54:306–326.

———. 1957. Un nouveau genre de Xanthophycée d'eau douce de la Forêt de Sénart: "*Chadefaudiothrix*." Rev. Algol. 3:97–102.

FRITSCH, F. E. 1933. Contribution to our knowledge of British algae, V. A British species of *Ecballocystis* (*E. fluitans* sp. nov.). J. Bot. 1933:187–196.

MEYER, R. L., AND A. J. BROOK. 1969. Freshwater algae from the Itasca State Park, Minnesota, II. Chrysophyceae and Xanthophyceae. Nova Hedwigia 17:105–112.

TARAPCHAK, S. J. 1972. Studies on the Xanthophyceae of the Red Lake wetlands, Minnesota. Nova Hedwigia 23:1–44.

WHITFORD, L. A., AND G. J. SCHUMACHER. 1969. A Manual of the Fresh-Water Algae in North Carolina. North Carolina Agric. Exp. Sta. Tech. Bull. No. 188:1–313.

———, AND ———. 1973. A Manual of Fresh-Water Algae. Sparks Press, Raleigh, North Carolina. 324 pp.

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First Record of the Masked Shrew in Western Kentucky

THOMAS FRENCH
Department of Life Sciences, Indiana State University,
Terre Haute, Indiana 47809

In Kentucky, *Sorex cinereus* was previously known to occur only at Big Black Mountain, Harlan County, in extreme southeastern Kentucky (Barbour and Davis 1974). Hall and Kelson (1959) included *Sorex cinereus* in western Kentucky along the Ohio River, and Barbour and Davis (1974) suggested that it might occur in northern Kentucky on the basis of records from adjacent Indiana and Ohio. Between 22 November and 17 December 1976, 6 pitfall can traps were set just west of U.S. 41, 0.7 miles (1.1 km) south of the Ohio River in Henderson County, Kentucky. From those cans, 1 white-footed mouse *Peromyscus leucopus*, 1 pine vole *Microtus pinetorum*, and 7 masked shrews *Sorex cinereus*, were captured. The cans were confined to 0.2 acres (0.08 ha) of river floodplain forest with numerous rotting logs and a thick mat of leaf litter.

The specimens compare favorably in coat color and body size to a series of 7 specimens from Hovey Lake, Posey County, Indiana (ISU 1080–1086). The means and ranges of standard body and skull measurements (Table 1) show little difference between the Indiana and Kentucky specimens. Cranial measurements follow Jackson (1928).

The type locality of *S. c. lesueurii* (Duvernoy) is the Wabash River Valley, Indiana. The exact locality was not listed, but specimens from all but southeastern Indiana have been referred to that subspecies by Mumford (1969). *Sorex c. lesueurii* is characterized by dark winter pelage, although much darker individuals are known to occur in Newton County, Indiana (ISU 996–998, 1910, 1911), 240 miles (ca. 380 km) north of Hovey Lake. The present locality is approximately 20 miles (32 km) east-northeast of Hovey Lake.

Ectoparasites were collected from 1 Henderson County *S. cinereus* and were identified by Dr. J. O. Whitaker, Jr., as *Protomyobia* sp., 11 (these are being studied further); *Orycteroxenus soricis*, 10; and *Amorphacarus hengererorum*, 1 male.

The present specimens (ISU 3635–3640 and UKy 5243) constitute the second locality for the species in Kentucky and the first record for the subspecies *lesueurii*.

I gratefully acknowledge J. O. Whitaker, Jr., for reviewing this manuscript.

LITERATURE CITED

BARBOUR, R. W., AND W. H. DAVIS. 1974. Mammals of Kentucky. University Press of Kentucky, Lexington, Ky. 322 pp.

TABLE 1.—MEANS AND RANGES OF STANDARD BODY AND SKULL MEASUREMENTS OF 2 SERIES OF *Sorex cinereus* FROM INDIANA AND KENTUCKY. ALL MEASUREMENTS ARE IN MILLIMETERS AND WEIGHTS ARE IN GRAMS

	Total length	Tail length	Hind foot length	Weight	Condylo-basal length	Cranial width	Maxillary width	Palatal length	Maxillary toothrow length
Henderson	89.3	36.7	11.9	3.2	15.6	7.5	4.4	6.5	5.9
County, Ky.	86–92	36–40	11.5–12.0	2.9–3.7	15.3–16.1	7.4–7.7	4.3–4.5	6.3–6.8	5.6–6.1
	n = 7	n = 7	n = 7	n = 7	n = 7	n = 7	n = 7	n = 7	n = 7
Posey	86.1	36.1	11.9	3.3	15.9	7.6	4.4	6.6	5.9
County, Ind.	81–91	33–39	11.0–13.0	3.1–3.6	15.4–16.4	7.5–7.7	4.3–4.5	6.4–6.8	5.8–6.0
	n = 7	n = 7	n = 7	n = 7	n = 6	n = 6	n = 6	n = 6	n = 6

HALL, E. R., AND K. R. KELSON. 1959. The Mammals of North America. Ronald Press, New York, N.Y. 2 vols., 1083 pp.

JACKSON, H. H. T. 1928. A taxonomic review of the American long-tailed shrews (genus *Sorex* and *Microsorex*). North Am. Fauna no. 51. Washington, D.C. 238 pp.

MUMFORD, R. E. 1969. Distribution of the mammals of Indiana. Ind. Acad. Sci., Monograph no. 1. Indianapolis, Ind. 114 pp.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 80–81

DISTINGUISHED SCIENTIST AWARD

Dr. Wallace W. Hagan

Last year, your Academy's Board of Directors created the Distinguished Scientist Award of the Kentucky Academy of Science. It was created to honor those among us who have distinguished themselves either as generators of new knowledge through the development of clever experiments or observations, whether at the research bench, out in the field, or within societies of man, or transmitters of new knowledge to new generations of young minds where information becomes weighed, evaluated, and incorporated into the body of knowledge of man, or as facilitators in the public sector who help the public and government to understand new knowledge and put it to effective use for the sake of the future of mankind.

I am delighted at this time to have the honor to make known the name of the Academy's 1977 Distinguished Scientist.

The person we are honoring this evening was born in Illinois and attended the University of Illinois, receiving his bachelor's, master's, and eventually his doctoral degrees in geology from that institution. While at the University of Illinois, he was honored with membership in Phi Beta Kappa.

Even before obtaining his doctorate, he was a petroleum geologist for the Wicklund Development Corporation and a consulting geologist in several municipalities in Kentucky and Illinois. Following completion of his graduate work, he became geologist in charge of the Ground Water Section on the Indiana Geological Society. He also served as a geologist and consulting geologist for a number of oil companies in Oklahoma, Kentucky, Indiana, Illinois, and Tennessee. Since 1958, he has been Director and State Geologist of the Kentucky Geological Survey.

He has published papers in paleontology and on oil and gas possibilities in various regions of the midwestern United States.

He has given extensively in the area of public service. Just as some examples, he was for 6 years a member of the Advisory Board of the Kentucky Geological Survey. From 1958 to the present, he has served as the Governor's representative on the Interstate Oil Compact Commission. He has been a member of the Kentucky Water Resources Council since 1958, and for 13 years served on the Research and Policy Committee of the Kentucky Water Resources Institute. He is a continuing member of the Committee on Radioactive Waste Disposal of the Kentucky Science and Technology Council, and has been a member of the Lower Mississippi Region Comprehensive Study Group since 1970. For 10 years, he was a member of the Advisory Committee on Water Data for Public Use of the United States Department of the Interior.

During that same time, he has been active in a number of professional societies, having risen to distinguished positions in each. As an example, he has been a long-standing member of the Association of American State Geologists, having risen through various offices to become its national President in 1968 and 1969. He also served for some years as a member of its Executive Board.

As another example, he has been Vice Chairman of the Southeastern Section of the Geological Society of America. In addition, he is a member of the American Association of Petroleum Geologists, having served on a number of their committees, including the Advisory Committee to Federal, State, and Local Agencies. He is not only a member of the Geological Society of Kentucky, but in 1966 served as the state President. This is only a small sample of this individual's participation in various local, state, and national professional societies.

In 1972, our recipient received the John Wesley Powell Award that was established in 1971 by the United States Geological Survey of the United States Department of the Interior. That award is given in recognition of the contribution that private citizens and groups have made to the furtherance of the USGS missions. Largely through the efforts of the man we honor this evening, extensive geological mapping of the Commonwealth of Kentucky has been accomplished. Kentucky is one of the few states with such complete mapping of its resources.

Thus, the person we honor tonight has had a distinguished career in his chosen profession and has made important and significant contributions in the public sector toward furtherance of the understanding and utilization of that information by society.

We are pleased to announce that the Academy's 1977 Distinguished Scientist is Dr. Wallace W. Hagan, Director and State Geologist of the Kentucky Geological Survey.

Thomas B. Calhoon, Chairman
Board of Directors

Response by Dr. Hagan

Dr. Calhoon, Mr. President, fellow members of the Kentucky Academy of Science, and guests, I appreciate very much being honored as recipient of the award of "Distinguished Scientist for 1977." I accept it with acknowledgment it was made possible by the accomplishments of the staff of the Kentucky Geological Survey, the cooperative programs with KGS and the United States Geological Survey in areal geologic mapping, water resources investigations, and topographic mapping; by the support of the Kentucky Department of Commerce, the University of Kentucky, and the Kentucky Development Cabinet.

The Kentucky and Federal governments, industry, Kentucky Chamber of Commerce, Agriculture–Kentucky Farm Bureau, the Kentucky Geological Survey Advisory Board, the people of Kentucky, and professional engineers and geologists have supported the KGS programs and made them possible.

The Areal Geologic Mapping Program that was commenced in 1960 as a cooperative program by KGS and USGS is the first time an attempt has been made to map the bedrock geology of a state this large at a scale of 1:24,000. The 767 quadrangles, each of which covers about 59 square miles, have all been field completed, and it is anticipated all will be printed by January 1979. This is a program of great economic value to all our people.

Again, I want to thank the Kentucky Academy of Science for the recognition of our work through me. It is indeed an unexpected privilege. I also thank my wife, Betty, for all the patience, understanding, and support she has given me during the years.

This is the last Academy meeting I will attend as your Director and State Geologist of the Kentucky Geological Survey as I am to retire 1 July 1978. My interest in the Academy, the geology of Kentucky, and the progress of the Survey will continue beyond that date.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 82–87

ACADEMY AFFAIRS

PROGRAM

Friday, 11 November 1977

1200–1600, CST REGISTRATION, Thompson Complex for Science–Central Wing

1200–1700 SCIENTIFIC EXHIBITS, Thompson Complex for Science–Central Wing

1300–1600 SECTIONAL MEETINGS (see following pages)

1830–2030 KAS ANNUAL BANQUET, Downing University Center Auxiliary Dining Room

Speaker: Damon Harrison
Commissioner of Energy
Commonwealth of Kentucky

2100–2300 HOSPITALITY HOUR, Red Carpet Inn

Saturday, 12 November 1977

0800–1200 SCIENTIFIC EXHIBITS, Thompson Complex for Science–Central Wing

0800–1000 REGISTRATION, Thompson Complex for Science–Central Wing

0800–0915 ANNUAL BUSINESS MEETING, Thompson Complex for Science–Central Wing, Room 129

0915–0930 COFFEE BREAK

0930– SECTIONAL MEETINGS (see following pages)

SECTIONAL PROGRAMS

Botany and Microbiology

Room 203 Thompson Complex for Science, North Wing

William Martin, Chairman, Presiding
Willem Meijer, Secretary

Friday, 11 November

1300 The causitive agent of reddening in lettuce. L. P. Elliot, Western Kentucky University.

1315 The effect of temperature and cell poisons upon the growth of *Saccharomyces cerivisiae* populations. Michelle Gausepohl, Western Kentucky University. (Sponsor: Herbert Leopold.)

1330 The taxonomic significance of experimental selection by vernalization in *Nuphar*. E. O. Beal, Western Kentucky University.

1345 Ecotypic differentiation in Ohio and Mississippi populations in *Acer negundo* L. Anthony Greco and Joe Winstead, Western Kentucky University.

1400 Effects of submergence on *Liquidambar styracflua* L. seedlings. Lynn N. Wellman and Joe E. Winstead, Western Kentucky University.

1415 Experimental synthesis on ectomychorrhizae with *Pisolithus tinctorius* on tree seedlings produced for strip mine reclamation. Dale M. Maronek and James W. Hendrix, University of Kentucky.

1430 Association on mammal occurrence in the ectomychorihoral fungus *Pisolithus tinctorius* with superior growth on pine seedlings on reclaimed strip mine sites. James W. Hendrix, Dale M. Maronek, and Claude Downing, University of Kentucky and Division of Reclamation, London, Kentucky.

1445 The Kentucky Nature Preserves Commission. Donald Harker, State Government, Frankfort.

Saturday, 12 November

0930 Index Herbarium Kentuckiensis. Stuart Lassetter, Eastern Kentucky University.

0945 Endangered and threatened plants of Kentucky. Progress report. Willem Meijer, University of Kentucky, and Mary Wharton, Georgetown College.

1000 Bald point, a forest and prairie complex in northern Kentucky. William S. Bryant, Thomas More College.

1015 The flora of Hardin County. Ray Cranfill, University of Kentucky.

1030 A new station for the filmy fern *Trichomanes boschianum* in Western Kentucky. Ronald R. Van Stockum, University of Louisville.

1045 The Inner Blue Grass and its tree vegetation. Julian J. Campbell, University of Kentucky.

1100 Lichen associations in relation to air pollution in the Inner Blue Grass. Martha Simpson, University of Kentucky. (Sponsored by Willem Meijer.)

1115 Geographic affinities of the bryophytes on the Red River Gorge. Susan M. Moyle, Centre College.

1130 Saxicolous bryophyte communities in the Red River Gorge. Mary Gallagher and Susan M. Moyle, Centre College.

1145 The Flora of the Kentucky River Bluffs in the Blue Grass Region. Willem Meijer, University of Kentucky.

1200 Election of officers for 1977–1978.

CHEMISTRY SECTION

Room 402 Thompson Complex for Science, Central Wing

Ilyas Ahmad, Chairman, Presiding
James Niewahner, Secretary

Friday, 11 November

1400 The role of different dietary carbohydrates on the body chemistry of animals in relation to cholesterol, lipid, lipoprotein levels, and certain serum enzymes levels. Ilyas Ahmad and Charlotte Dingels, Kentucky State University.

1430 Characterization of nitrogen compounds from coal liquids. Tay-Yen Lin and Norman Holy, Western Kentucky University.

Saturday, 12 November

0930 The effect of diet on the number and size of adipose cells in rats. Lydia C. Maness and Sue A. Debes, Kentucky State University.

1000 Gas chromatograph and flame ionization analysis of ethylene gas production. Steve Estok. (Third place award in Chemistry ISEF, Cleveland, Ohio, 1977), Western Kentucky University.

1020 Polymerization of some metallophthalocyanines. Issa Jabra and Robert Farina, Western Kentucky University.

1040 Stereochemistry of 1-tertiary butyl-1,4-dihydronaphthalene and 1,4-di,ter-butyl-1,4-dihydronaphthalene. Abdol Haji-Hossien-Nejad and Normal L. Holy, Western Kentucky University.

1100 Kinetic study of the peroxysulfate–chloride reaction. Jim Niewahner, Northern Kentucky University.

GEOGRAPHY SECTION

Note: Geography will have concurrent sessions Friday.

Friday, 11 November

URBAN GEOGRAPHY—Room 337,
Environmental Science and Technology Building

1300 Geography and Planning. The Eastern Kentucky University experience. R. L. Marionneaux, Eastern Kentucky University.

1315 The areal distribution of three components of the urban social profile of metropolitan Perth. Thomas P. Field, University of Kentucky.

1330 Occupational structure of Louisville, 1832. A. William Dakan, University of Louisville.

1345 An examination of variations in quality of life among Kentucky's urban places. Dennis E. Quillen, Eastern Kentucky University.

1400 Factorial urban ecology of metropolitan Lexington. Dinker I. Patel, Kentucky State University.

CULTURE AND DEVELOPMENT—Room 337,
Environmental Science and Technology Building

1415 Growth management in the Bluegrass. T. J. Kubiak, Eastern Kentucky University, and J. V. Panayotoff, Department of Transportation, Frankfort.

1430 Cultural determinism in a difficult physical environment. Gary C. Cox, Morehead State University.

1445 Louisiana sugarcane: an industry in change. Arthur Frank Perkins, Eastern Kentucky University.

ENVIRONMENTAL GEOGRAPHY—Room 338,
Environmental Science and Technology Building

1300 Tornadoes of 27 March 1890: an approach to the study of severe weather phenomena in Kentucky's past. Marvin W. Russell, Western Kentucky University.

1315 Methods for assessing the influence of winter temperatures on natural gas consumption. Glenn Conner, Western Kentucky University.

1330 Quaternary fluctuations and areal extent of drifting arctic sea ice. Anthony O. Clarke, University of Louisville.

1345 Ducktown: a making of a desert. James W. Taylor, Western Kentucky University.

KENTUCKY GEOGRAPHY—Room 338,
Environmental Science and Technology Building

1400 Ellen Churchill Semple: a portrait. Cynthia Cooke, University of Louisville.

1415 A proposed "Pronouncing Gazetteer of Kentucky Place Names." William A. Withington, University of Kentucky.

1430 Wet, dry, and damp: alcohol and Kentucky counties. Tom Spinks, University of Louisville.

1445 Visitation to Kentucky reservoir parks: a prediction for Taylorsville. John L. Anderson, University of Louisville.

GEOLOGY SECTION

Note: Geology will have concurrent sessions Friday and Saturday afternoons.

Friday, 11 November

GENERAL GEOLOGY—Noland Fields, Chairman
Room 323, Environmental Science and Technology Building

1300 Source of the heavy minerals in the Wilcox and Claiborne formations in Henry, Weakley, and Carroll counties, Tennessee. Armin L. Clark, Murray State University.

1325 The Devonian-Mississippian paracontinuous contact in southern Kentucky. J. E. Conkin, University of Louisville, and B. M. Conkin, Jefferson Community College.

1350 Relationship of sieve size frequency distribution data to thin-section textural data: a progress report. Thomas McLoughlin, Morehead State University.

1415 Some hydrologic characteristics of a forested watershed in eastern Kentucky. Everett D. Springer and George B. Coltharp, University of Kentucky.

1440 Multispectral scanning information on the highlands of the moon. C. Ronald Seeger, Western Kentucky University.

COAL—Norman C. Hester, Chairman; Room 328, Environmental Science and Technology Building

1515 Geochemistry of coal-bearing sediments in eastern Kentucky. Roy Dale Merritt, Eastern Kentucky University. (Sponsor: Norman C. Hester).

1540 The occurrence and distribution of sulfur in coal bearing rock in Eastern Kentucky. Norman C. Hester, Eastern Kentucky University.

1605 Interval correlation of western Kentucky coals. L. Chyi, University of Kentucky.

1630 Petrology, mineralogy, and chemistry of Hazard #4 tonestin. Stanley Stevens, Eastern Kentucky University.

SPECIAL SESSION—C. Ronald Seeger, Chairman; Room 328, Environmental Science and Technology Building

Invited papers on geology and tectonics of western Kentucky

0930 Survey of the tectonic setting of the central midcontinent. Virginia Lee Hagee and C. Ronald Seeger, Western Kentucky University.

0955 Aeromagnetic and gravity anomalies related to structure in western Kentucky. R. W. Johnson, Tennessee Valley Authority, and G. R. Keller, University of Texas at El Paso.

1020 Geology of the Reelfoot Basin. Howard R. Schwalb, Kentucky Geological Survey, Henderson, Kentucky.

1045 Interpretation of microgravity surveys of the Tiptonville Dome. Susan K. Towe, Parrish N. Erwin, Jr., and Richard G. Stearns, Vanderbilt University.

1110 Earth resistivity of samples in the field and laboratory. Jau-Ping Tsau, Richard G. Stearns, and Robert G. Perry, Vanderbilt University

1135 Tracing a fault scarp near Reelfoot Lake. Richard G. Stearns, Jau-Ping Tsau, Susan K. Towe, and Parrish N. Erwin, Jr., Vanderbilt University.

1200 Noon meal.

AFTERNOON SESSIONS

GEOCHEMISTRY AND SEDIMENTATION—Gary Kuhnhenn, Chairman; Room 323, Environmental Science and Technology Building

1315 U-Th geochemistry of Devonian black shale in Kentucky. W. H. Blackburn, P. A. Davis, and G. Makowitz, University of Kentucky.

1340 Stratigraphy and geochemistry of Chattanooga shale in Pulaski County, Kentucky. Dennis Swager and Eugenion Nunez, University of Kentucky. (Sponsor: Perry B. Wiggley.)

1405 Depositional history and paleoecology of carbonate mud mounds within the Fort Payne (lower Mississippian) of northern Tennessee. Robert B. Lieber and W. C. MacQuown, University of Kentucky.

1430 Preliminary microscopic study of the Devonian black shales from eastern Kentucky. Michael L. Miller and Frank R. Ettensohn, University of Kentucky.

1455 Clay mineralogy and depositional environment of some interbedded green and black shale. Lewis P. Scott IV, Eastern Kentucky University. (Sponsor: Perry B. Wiggley.)

GENERAL GEOLOGY—Ronald Dilamarter, Chairman; Room 328, Environmental Science and Technology Building

1315 Depositional Environment of the Strodes Creek member of the Lexington Limestone. Hamidedin Marashi and Perry B. Wiggley, Eastern Kentucky University.

1340 Ojo Caliente tuff ring of the Rio Grande Rift, Rio Arriba County, New Mexico. S. Judson May, Eastern Kentucky University.

1405 Clay mineralogy of the overburden in eastern Kentucky. Clinton C. Wetmore and Stanley Stevens, Eastern Kentucky University.

1430 Louisville Meteorite: ordinary chondrite L6 with shock metamorphic textures. Graham Hunt, University of Louisville.

1455 Quaternary topographic changes on glacial drifts in Iowa. Ronald R. Dilamarter, Western Kentucky University. (Sponsor: C. Ronald Seeger.)

1520 Sectional Business Meeting, Room 328, Environmental Science and Technology Building.

PHYSICS SECTION

Room 403, Thompson Complex for Science, Central Wing

James Parks, Chairman, Presiding
Manuel Schwartz, Secretary

Friday, 11 November

1300 KAPT Business Meeting, James Parks, President, Presiding.

1330 Report—AAPT actions. Frank Six, Western Kentucky University.

1340 Simplified statistics for introductory physics. Peter W. Murphy, Centre College.

1350 Diffraction of light by an array of filaments. D. Bryant, Western Kentucky University.

1400 Search for a solid state laser oscillator at 1.315 micrometers. E. Dorman, Western Kentucky University.

1410 Magnetic braking during star formation. Robert C. Fleck, Jr., University of Kentucky.

1420 Magnetohydrodynamics and inhomogeneous cosmologies. A. Fennelly, Western Kentucky University.

1430 Emission-line galaxies. T. Bohuski, Western Kentucky University, and D. Weedman and A. Fairall, Vanderbilt University.

1440 Basic experiments with silicon solar cells. Randall Winchester and Buford Anderson, Murray State University.

1450 Advanced experiments with silicon solar cells. Steven Hicks and Buford Anderson, Murray State University.

Saturday, 12 November

0930 Synergistic effects of ultraviolet radiation on mammalian cells and viruses. B. E. Cobb and T. P. Coohill, Western Kentucky University.

0940 Dynamical evolution of the interstellar gas towards the formation of stars: the "Gravitational Slingshot." F. O. Clark, University of Kentucky.

0950 Total neutron production cross section for ^{29}Si (a,n) ^{32}S. D. S. Flynn, R. Hershberger, F. Gabbard, and J. L. Weil, University of Kentucky.

1000 Cross section and strength functions for ^{107}Ag (p,n) ^{107}Cd, and ^{109}Ag (p,n) ^{109}Cd. R. Hershberger, D. S. Flynn, F. Gabbard, and J. L. Weil, University of Kentucky.

1010 Positron annihilation and molecular polarizability. D. C. Huang, Catalytics and Chemicals, Inc., Louisville, and W. F. Huang, University of Louisville.

1020 Study of range, stopping power, and straggling of alpha particles in air. P. J. Ouseph and A. Mostovych, University of Louisville.

1030 Traffic noise near the Thomas More College campus—predictions. D. P. Roenker and J. Boyle, Thomas More College.

1040 Optimizing travel times in a mass transit system. V. A. O'Connell and J. E. Lang, Thomas More College.

1050 Fine structure in F and G states of helium. K. B. MacAdam, University of Kentucky.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY SECTION

Room 130, Thompson Complex for Science, North Wing

Thomas F. Coohill, Chairman, Presiding
John Meger, Secretary

Friday, 11 November

1400 Evidence for bifunctionality in the his B enzyme of *Salmonella typhimurium*. Eugene J. Hoffman, Western Kentucky University.

1415 Radiation enhanced (Weigle) reactivation of herpes virus. Leslie C. James, Thomas P. Coohill, and Sharon P. Moore, Western Kentucky University.

1430 Effect of 8-methoxypsoralen on Weigle reactivation of herpes virus. Leslie C. James and Thomas P. Coohill, Western Kentucky University.

1445 A mathematical model for maize competition and yield emphasizing harvest index. Marvin W. Russell, Western Kentucky University.

1500 Does the murine bone marrow cell population contain immunocompetent cell for cellular immunity? F. Morgado, Western Kentucky University.

Saturday, 12 November

0930 Multiple molecular forms of porcine enolase; physical and chemical properties. William Farrar, Eastern Kentucky University. (Sponsor: Sanford L. Jones.)

0945 The effect of salpingectomy on maintenance of pseudopregnancy, uterine and ovarian weights in the rat. Sanford L. Jones, Eastern Kentucky University.

1000 Folic acid absorption in pregnancy. Debra K. Pearce, Northern Kentucky University.

1030 Computer designed contact lenses. F. D. Bryant, Western Kentucky University.

1100 Effects of diayepam (valium) on the medullary respiratory neurons of anesthetized cats. Leon D. Wang and Donald T. Frazier, University of Kentucky.

1130 Sectional business meeting and election of officers.

SCIENCE EDUCATION SECTION

Room 338, Environmental Science and Technology Building

Shaw Blankenship, Chairman, Presiding
Terry Wilson, Secretary

Saturday, 12 November

0930 An experiment in an integrated science–math–education component in the elementary teacher education program. Gary Boggess and Arvin Crafton, Murray State University.

0955 Utilizing a mobile laboratory to teach environmental concepts. Nancy Stearns, Museum of Natural History and Science, Louisville, Kentucky.

1020 Participatory versus passive planetarium programs. Jack Fletcher, Eastern Kentucky University.

1045 Educational activities of the northern Kentucky Audubon Club. Michael O'Brien, Program Director Northern Kentucky Audubon Club.

1110 Statewide staff development training in science education. Frank Howard, Kentucky Department of Education, Frankfort.

1135 Energy education curriculum project. Terry Wilson, Kentucky Department of Education, Frankfort.

1200 Business session.

PSYCHOLOGY SECTION

Room 349, Environmental Science and Technology Building

Friday, 11 November

1300 The effects of modeling on personal space in white subjects in relation to a black or white confederate. Rita C. Masden and Richard Shuntich, Eastern Kentucky University. (Sponsor: Dr. William H. Watkins.)

1320 Conformity within the fraternity system. Mark Davis and Brent White, Centre College.

1340 Indirect tests of theories of dreaming using presleep manipulation. Donald Brown and Cathy Kassab, Centre College.

1400 Learning of 'identity' and 'difference' roles in the pigeon. David E. Hogan, Charles A. Edwards, and Thomas R. Zentall, University of Kentucky. (Sponsor: James S. Calvin.)

1420 Passive avoidance learning in the young domestic chick. Michael Osborne, Bruce A. Mattingly, and James F. Zolman, University of Kentucky.

1440 Caffeine–amphetamine interaction: route of injection and prior caffeine treatment. Brent White and Don Harkins, Jr., Centre College.

1500 Functional recovery after spaced sequential destruction of the frontal lobes in the rat. Charles Goodlett and Arthur Nonneman, University of Kentucky.

Saturday, 12 November

0930 The effects of apomorphine on spontaneous activity in rats. Ronald L. Skidmore, Morehead State University. (Sponsor: Dr. Francis R. Osborne.)

0950 Caffeine suppression of barbituate sleep time: Dose response and drug order relationships. Brent White and Lynn Elliot, Centre College.

1010 Effects of response topography with controllable vs. uncontrollable stress in rats. Francis H. Osborne, Ronald L. Skidmore, Allen L. Levay, Morehead State University.

1030 The effects of retinal eccentricity and orientation on perceived length. Jack G. Thompson and Katherine A. Fowler, Centre College. (Sponsor: Dr. Brent White.)

1050 The role of rule difficulty and familiarity in adult concept formation. Jack G. Thompson and Joanne H. Cornell, Centre College. (Sponsor: Dr. Brent White.)

1110 The effects of population density on social behavior of Kentucky residents. Bradley S. Moore, Morehead State University. (Sponsor: Dr. Francis H. Osborne.)

1130 Business meeting.

SOCIOLOGY SECTION

Room 402, Environmental Science and Technology Building

Craig Taylor, Chairman, Presiding
K. M. George, Secretary

Friday, 11 November

1300 Evaluation of effect of occupational sex dominance by probability estimation. Audrey Jackson, Western Kentucky University.

1330 The phenomenological critique of social science. Edward Armstrong, Murray State University.

1430 Sectional business meeting. Election of 1977–1978 officers.

Saturday, 12 November

0945 Workshop in social science simulations. Paul Wozniak and Thomas Dunn, Western Kentucky University.

ZOOLOGY AND ENTOMOLOGY SECTION

Room 101, Thompson Complex for Science, North Wing

Henry H. Howell, Chairman, Presiding
Paul H. Freytag, Secretary

Friday, 11 November

1300 The mammals of Lilly's Woods. William W. Lewis and M. Pete Thompson, Eastern Kentucky University.

1315 Economics of woodchucks in central Kentucky. M. Pete Thompson, Eastern Kentucky University.

1330 Winter bird roosts in the Bowling Green area, with analysis of microbial flora and diet of the birds. H. E. Shadowen and L. P. Elliott, Western Kentucky University.

1345 Scanning electron microscopy of the scolex of the cestode *Onygmatobothrium musteli.* Fred H. Whittaker, University of Louisville.

1400 Long-term survivorship of *Drosophila* in oxygen enriched atmospheres: a multiple generation approach. Gerrit Kloek, Kentucky State University.

1415 *Drosophila* survivorship in hypobaric atmospheres: a preliminary discussion. Linda Mahoney, Kentucky State University.

1430 The effect of mutations on the survival of *Drosophila melanogaster.* Becky Unthank, KJAS Winner of Zoology Section.

1445 Sectional business meeting.

Saturday, 12 November

0930 Population dynamics of *Sitona hispidula* adults in alfalfa and red clover in Kentucky. Gary L. Leibee, University of Kentucky.

0945 The early hair streak *Erora laeta* in Kentucky (Lepidoptera: Lycaenidae). Charles V. Covell, University of Louisville.

1000 Biology of *Caliroa quercuscoccineae* (Hymenoptera: Tenthredinidae). Eric Johnson, University of Kentucky.

1015 Life cycle of *Gonatopus bicolor* (Hymenoptera: Dryinidae). Paul H. Freytag, University of Kentucky.

EXHIBITORS

Beckman Instruments
Carl Zeiss
Carolina Biological Supply Company
Estes Industries
Graphic Controls Corporation
Harvard Apparatus Company, Inc.
(Devices for Science, Inc.)
Olympus Corporation of America
Southern Biology Supply

Exhibits are in the lobby of the Thompson Science Complex, Center Wing during 11 November, 1200–1700, and 12 November, 0730–1500.

The Academy acknowledges the support of all exhibitors and recognizes that the meeting is enhanced by displays of materials of use to science educators.

Trans. Ky. Acad. Sci., 39(1–2), 1978, 88–91

The Sixty-Third Annual Business Meeting of the Kentucky Academy of Science

Western Kentucky University, Bowling Green, Kentucky

11 and 12 November 1977

Hosts: Drs. Marvin Russell and Wayne Hoffman

Minutes of the Annual Business Meeting

The meeting was called to order by President Charles Payne at 0805 in Room 129, Thompson Complex for Science, Central Wing, with about 60 members in attendance.

After a motion by Secretary Seay and a second from the floor, the Minutes of the 1976 Annual Business Meeting at the University of Kentucky, as recorded in TRANSACTIONS Vol. 38(1–2), were approved.

The Secretary then moved to accept all members that joined during 1976. The motion was seconded and carried.

The Secretary announced that membership has increased to 538 individual members and a total mailing list of close to 600 (as of 7 November). The Secretary was notified of one death during the year: Dr. Ward Sumpter, Western Kentucky University.

The Treasurer's Report was given by Dr. Bartlett Dickinson. The report was audited by Genevieve Clark, Dwight Lindsay, and Tom Seay (Chm.) and found to be in good order.

Treasurer's Report to the Audit Committee

Kentucky Academy of Science

11 November 1976–4 November 1977

Cash in Citizens National Bank, Bowling Green, Kentucky, 11 November 1976		$ 7,529.83
Check outstanding to JKAS, 11 November 1976		500.00
		$ 7,029.83
Receipts:		
Subsidy from State	$ 6,000.00	
Membership dues	1,582.50	
Annual Meeting	873.85	
Subscriptions to Transactions	458.00	
Transactions to University of Louisville	375.00	
AAAS Research Grant	128.00	
Floristic Grant transfer	500.00	
Botany Foundation	2,000.00	
	$11,917.35	$11,917.35
		$18,917.18
Disbursements:		
Annual Meeting	$ 1,296.69	
AAAS Research Grants	128.00	
Refund to National Science Foundation	300.86	
Certificate of Deposit, Botany Foundation	2,000.00	
Operating expenses—stationery, etc.	121.24	
Floristic Grant	500.00	
Dues to AAAS, 1977	24.50	
Publication of Transactions	7,337.00	
	$11,708.29	
Balance		$ 7,238.89
Cash in Farmer's National Bank, Georgetown, Kentucky, 4 November 1977		$ 7,238.89
Savings account, Lexington Federal Savings and Loan		1,342.69
Savings account, First National Bank, Georgetown		71.58
Savings account (Foundation), First National Bank, Georgetown		6.29
Savings account (Floristic Grant), Citizens National Bank, Bowling Green		1,613.82
Certificate of deposit (Botany Foundation), Citizens National Bank, Bowling Green		2,843.16
Certificate of deposit (Botany Foundation), First National Bank, Georgetown		2,000.00
Total Assets		$15,116.43

Dr. Payne called for the following committee reports:

1. **Committee on Membership.** Dr. Batch reported that the membership drive was more successful than the past drive with about a 10 percent increase in membership. (The Secretary noted that Dr. Batch led the way with 8 new members.)

2. **Committee on Legislation.** No report.

3. **Committee on Publications.** Dr. Krumholz presented the following written report to the Secretary:

During 1977, 2 issues of Volume 38 of the *Transactions* were published and distributed to the membership.

Volume 38(1–2) consisted of 110 pages that included 16 papers, the Distinguished Scientist Award, Academy Affairs, and News and Comment. Volume 38(3–4) consisted of 40 pages that included 10 papers, News and Comment, and the Index and Contents for Volume 38. The cost for Volume 38(1–2) was $4,641.57 and that for Volume 38(3–4) was $2,156.40 for an annual total of $6,797.97. Thus, the cost per page for the entire page for the entire volume was $41.45 including all blank pages and covers.

The subjects of the 26 papers in Volume 38 were distributed among the various disciplines as follows: Zoology, 16; Chemistry, 3; Botany, 3; Geology, 2; Bacteriology, 1; and Scientific Literature, 1. Pages occupied by the various disciplines in Volume 38 were: Zoology, 92; Chemistry, 15; Botany, 8; Geology, 13; Bacteriology, 6; and Scientific Literature, 1.

The size of Volume 38 represents an increase of 39 pages over that of Volume 37 for 1976 that included 19 papers distributed among the disciplines as follows: Zoology, 10; Botany, 7; and Chemistry, 2. Pages occupied by those disciplines were: Zoology, 44; Botany, 40; and Chemistry, 2. It also represents an increase of 3 disciplines included in the publication.

It is hoped that greater numbers of papers from disciplines other than Zoology and Botany will be forwarded to the editorial office. We have established deadlines of 1 January and 1 July for sending completed and edited manuscripts to the printer. Thus, any prospective author should submit a manuscript at least 3 months in advance of those deadlines so that there is ample time for review and revision.

In addition to the above report, Dr. Krumholz announced that the Executive Committee voted that all authors of papers published in the TRANSACTIONS must be members of the Academy. The Board of Directors was asked to approve that action. The Board approved.

Dr. Krumholz also announced that, beginning with Volume 39 of the TRANSACTIONS, there will be page charges of $15.00 per printed page or portion thereof.

4. Committee on Public Science Education. Dr. Ted George presented the following report:

We have proposed to the Kentucky Council on Teacher Education and Certification that there should be 3 distinct areas of certification for science teachers: Elementary (K–6), Middle School (5–9) and Secondary (9–12) and we also specified what we thought certification requirements should be for those science teachers. Our proposal for Elementary certification was rejected. The Council agreed to study the Middle School certification for all teachers and set up its own committee to study the feasibility and make recommendations. This committee recommended a separate certification area for Middle School and also recommended certification requirements of 24 semester hours in science for science teachers in Middle School. Of the 24 hours, 6 hours at least must be in Biological Science, 6 hours in Physical Science, and 6 hours in Earth Science. One laboratory would be required in each Biological Science and Physical Science.

In our opinion, this preparation would be totally inadequate for anyone to teach the science courses now available at grades 7, 8, and 9. The proposal has passed the Kentucky Council on Certification as well as the State Board of Education and is due to be implemented in September 1979.

We have been told that many other groups have reservations concerning these new Middle School Certification Guidelines and that hearings will be held as to whether the Guidelines will be optional or mandatory for the Middle School teachers. If you have an opportunity to attend one of the meetings, you should be sure to register your opinion. A full report of the Committee is available.

5. State Governmental Science Advisory Committee. Dr. Marvin Russell reported that he had attended a meeting with the Governor's Cabinet. It was scheduled for 10 min, but turned into a 45-min session at their insistence. A meeting was held at the request of Mr. Harry Snyder, Executive Director of the Council on Higher Education, to discuss the updating and expansion of the Scientific Manpower Registry. The possibility of the Council assuming the major responsibility for maintaining the registry was explored. Dr. Russell will serve as liaison to the Academy President until such time as the new president elects to appoint a committee or take other action.

"The National Science Foundation will provide up to $2,500,000 in study grants to be used by the States to identify and analyze potentially useful ways in which State and local governments can increase their capacities for using science, engineering, and technology in meeting the needs of their citizens. Up to $25,000 each for the Executive and Legislative Branches of each State government will be made available as the Federal share of the cost of the study grants.

"This planning program is intended to provide State governments with assistance in the development or improvement of the policy formulation processes in their States. Funds will be provided to assist a State in identifying the need for, and the contributions that can be made by, policy analyses, research results, and decisionmaking process of their State, in both the Executive and Legislative Branches." (Taken from the program announcement.)

KAS has been asked by one of the state agencies to explore possible areas of mutual interest.

6. **Committee on Botanical Research Fund.** Dr. Joe E. Winstead reported the following awards:

Ms. Deborah Otte, graduate student at the University of North Carolina, Chapel Hill, $400.00, to help fund her study "A Vegetational Analysis in Relation to Environmental Factors of the Red River Drainage System in Eastern Kentucky."

Ms. Sally Arnold, graduate student in Biology at Western Kentucky University, $100.00, to help support her study "Determination of Environmental vs. Genetic Variability within the *Lindernia dubia–anagallidea* Complex."

These awards will be made in January 1978 upon receipt of dividends and interest from the KAS Foundation for Botanical Research endowment.

7. **KAS–AAAS Grant Committee.** Dr. Joe E. Winstead gave the following report.

Members of the KAS–AAAS Grant Committee after study of proposals submitted to the Academy have selected 2 applications to share the 1977–1978 award. Recipients are: Sister Mary Leon Riney, St. Mary High School, Paducah, Kentucky. Grant monies to be used to help purchase a Hach water analysis kit for student use in environmental chemistry. Mr. Richard A. Van Enk, Department of Biology, Western Kentucky University. Funds to help defray incidental expenses for his proposed study entitled "Isolation and Enumeration of Yeasts of Medical Importance from the Barren River." It is the intent of the Committee that the funds available for 1977–1978 be divided equally between Sister Riney and Mr. Van Enk.

8. **Floristic Grant Committee.** Dr. Marian Fuller reported that the committee had met to formulate general procedures, but there was no award to announce at this time. Other committee members are Arland Hotchkiss, University of Louisville, and John Thieret, Northern Kentucky University.

At this point, President Payne exhibited the new Certificate of Membership that will be made available to all new members automatically and to all other members upon request. Appreciation was expressed to Herbert Leopold for making the certificate available to the Academy.

9. **The Junior Academy.** Herbert Leopold reported that the Junior Academy is solvent and operating smoothly. The April Symposium held in Lexington drew an attendance of 225–250 with 80 papers presented. Steve Estok, Warren East High School, won third place honors in the chemistry section of the International Science and Engineering Fair. He will present his paper at the AAAS meeting in Washington.

10. **AAAS Representatives.** Dr. Branley Branson reported that there had been considerable correspondence regarding various offices and new groups within the AAAS, but there was nothing major at this time to report to the Academy.

President Payne asked for the assembled members to act on the dues increases as presented in the Academy Newsletter. The dues increases were:

Active Membership	$ 10.00
Student Membership	7.00
Sustaining Membership	25.00
Life Membership	100.00
Institutional Affiliation*	50.00
	(or multiples/year)

* The Executive Committee and Board of Directors voted to change the name "Contributing Membership" to "Institutional Affiliation."

There was no discussion and the motion to accept the new dues figures was passed without objection.

Once the above increase was accepted by the assembled members, President Payne announced the receipt of $6,000.00 from the Governor's Contingency Fund and called for the report of the Resolutions Committee.

11. **Resolutions Committee.** Dr. John Philley submitted the following resolutions, that were unanimously accepted:

Resolution No. 1:

Whereas, Western Kentucky University has graciously served as the Host Institution for the Sixty-third Annual Meeting of the Kentucky Academy of Science, and whereas Dr. Marvin Russell, Dr. Wayne Hoffman, and others at Western Kentucky University have worked diligently to make the meeting a success and,

Whereas, Western Kentucky University has made outstanding contributions to scientific thought and leadership,

Therefore, be it resolved herewith:

a. That the Kentucky Academy of Science expresses its appreciation to Western Kentucky University and the above individuals, and that the Academy's Secretary be instructed to so inform them.

b. That the Kentucky Academy of Science congratulates Western Kentucky University for being an outstanding institution of higher education in Kentucky and our Nation and for promoting science through instruction, research, and public service.

Resolution No. 2:

Whereas, the University of Louisville and Morehead State University are among the outstanding institutions of higher education in the Commonwealth of Kentucky and have been instrumental in providing significant leadership to the Kentucky Academy of Science,

Therefore be it resolved herewith:

That the Kentucky Academy of Science expresses its appreciation to the University of Louisville

and to Morehead State University for their institutional affiliations with the Academy, and that the Academy's Secretary be instructed to so inform these institutions.

President Payne expressed his appreciation to Dr. Krumholz for his fruitful effort in obtaining $500 from the University of Louisville as an institutional affiliation. Modesty prevented him from taking any credit for the $250 institutional affiliation of Morehead State University. Members of the other institutions of higher education were invited to give their institution the privilege of participating!

It was announced that the Executive Committee had accepted an invitation from Eastern Kentucky University for the next annual meeting. The dates will be announced later.

The chair then recognized the chairman of the nominating committee, Dr. Krumholz (assisted by Henry H. Howell and William S. Bryant), who presented the following:

President Elect: Sanford L. Jones, Eastern Kentucky University

Vice President: Rudolph Prins, Western Kentucky University

Secretary: Thomas N. Seay, Georgetown College

Treasurer: Bartlett C. Dickinson, Georgetown College

Members of the Board of Directors to 1981: Donald C. Haney, Eastern Kentucky University; William F. Wagner, University of Kentucky

Director of the Junior Academy: Herbert Leopold, Western Kentucky University

AAAS Representatives: Branley Branson, Eastern Kentucky University; John Carpenter, University of Kentucky

There were no nominations from the floor and the above slate of officers was elected by acclamation.

There being no further business, President Payne became Past President Payne by introducing the new President, Charles Kupchella. President Kupchella listed as his priorities for the new year:

1. Membership expansion. Dr. Batch's impetus should spur the Academy in both increasing and giving better balance to the membership of the Academy.
2. Seeking more permanent state support as one way to improve the *Transactions* (along with implementation of page charges and dues increase).
3. Enhance visibility of the Academy and scientific endeavor. Attention was called to the report of Lloyd and Associates indicating the poor standing of Kentucky in receipt of Research and Development funds.
4. The desire to visit as many campuses as possible in the course of the year, perhaps giving a paper along the lines of "Cancer: The Ultimate Environmental Insult."

With those comments, the meeting was adjourned at 0915.

Thomas Seay, Secretary
Kentucky Academy of Science

Trans. Ky. Acad. Sci., 39(1–2), 1978, 92–94

NEWS AND COMMENT

President's Remarks

Science is far more of an entity than any of its subsets. While physiology, psychology, sociology, chemistry, and other scientific disciplines share the same methodologic approaches to the quest for new knowledge, they overlap in scope and have rather indistinct boundaries. It is appropriate that there are organizations that bind *scientists* together outside their narrow disciplines to provide a framework from which to deal with the problems of science and of society. The interaction among scientific subdivisions will become increasingly important as we deal with enormously complicated problems that require multidisciplinary approaches. This is also *Kentucky Science*, and this, too, is becoming more important as we face increasingly complex socioscientific problems within the Commonwealth.

Recently, I reflected on the things that stimulated me to become more involved in the work of the Kentucky Academy of Science. In addition to the obvious opportunities for good fellowship and for getting to know my colleagues throughout the state, there was the challenge presented in the report on Federal Research and Development funding in Kentucky, written several years ago by Dr. William Lloyd. That report revealed that Kentucky ranked fifty-first behind forty-nine other states and Washington, D.C. in federal dollars coming back to the state for research development. The report did not offer an explanation for this state of affairs, in fact it discounted several of the more likely reasons, e.g., our low standing remained the same even if per capita income of federal tax dollars contributed by Kentuckians was taken into account. Since one of our objectives as an Academy of Science is to encourage scientific research, that report indicates that our work is cut out for us. I will call on appropriate state officials to join with us in an evaluation of our current status in science and technology as a first step toward doing something about any inappropriate difference between where we are and where we ought to be.

Overall, I intend to help maintain the increasing momentum the Academy has enjoyed in recent years under the leadership of Dr. Charles Payne, Dr. Fred Brown, and others. We have enjoyed several years of state support for the publication of the *Transactions* and I will try to secure a more permanent base of such support, perhaps related to some degree of formal association between the Kentucky Academy of Science and State Government. We need a more visible Academy with a more visible relationship with other of the Commonwealth's institutions so that we can work more effectively to upgrade science and technology and those qualities of life linked to our science and technology. The *Transactions of the Kentucky Academy of Science* under the leadership of Dr. Krumholz has been upgraded considerably in recent years to the point where it is now a first-rate publication in every way by which quality can be measured. The institution of page charges is a positive step toward a permanent base from which that level of excellence can be maintained. The Board of Directors has enjoyed a new sense of purpose in recent years under leadership of Dr. John Philley and Dr. Thomas Calhoon. I look forward to working with the Board of Directors in the coming year as it continues its "Distinguished Scientist Award" and the implementation of other innovative ideas. Last year, the Academy enjoyed more than a ten percent increase in membership largely as a result of the work of Dr. Donald Batch and his Membership Committee. Dr. Batch has agreed to continue to work to make the membership of the Academy even more representative of the scientific interests throughout Kentucky. I am dedicated to involving previously uninvolved individuals in the work of the Academy on various committees and in other Academy activities. A gratifying number of members of the Academy have come forward offering to help. Some of them

have been long-time, faithful supporters of the Academy, and a significant number have been persons new to the governance of the Academy and its committees. This "new blood" is absolutely essential to the continued revitalization, vigorous growth, and success of the Kentucky Academy of Science.

Overall, I sense that the Academy is becoming increasingly capable of making significant progress toward its goals. I am delighted and grateful to be part of what I perceive to be a good thing getting better. I look forward with anticipation to further positive developments in the years ahead.

Membership Certificate Dr. Herbert Leopold and his colleagues of Western Kentucky University have designed and printed handsome membership certificates now available to all members of the Academy. The certificate is on high quality parchment, 8.5 × 11 inches, suitable for framing. It is intended to present all *new* members with such a certificate. Longstanding members may also receive a certificate of their own by requesting one, in writing, from the Secretary, Dr. Thomas N. Seay, Georgetown College, Georgetown, Kentucky 40324.

Tax Court Ruling Our printer, Allen Press, Inc., Lawrence, Kansas, has called to our attention a recent decision by the United States Tax Court that is of interest to our members. The decision of the Court in the case of Robert E. Drury vs. Commissioner, 36 T.C.M. 835 (1977) upholds the right of a scholar to deduct the costs of publication of his research from his income as ordinary business expense.

Dr. Drury wrote an article judged to be of scientific value, but could not get it published without cost to himself, so he paid for the publication of the article. He deducted the cost of payment for the publication from his federal income tax return as ordinary and necessary business expense under Section 162 of the Internal Revenue Code of 1954. The Internal Revenue Service disallowed his deduction and the matter was taken to Tax Court. The Tax Court upheld Dr. Drury's deduction, and recognized that "the expenditure for the publication of his article were ordinary and necessary business expenses within the meaning of Section 162."

Recently, Allen Press had their local attorney review the case, and the following is his summary:

"Based on the Tax Court's holding, it appears that the principal criteria for securing the deduction of publication costs for a scientific article or monograph are as follows: (1) that the author is expected to publish as a part of his job responsibilities, (2) that he cannot obtain cost-free publication in a scientific journal, and (3) that he needs to publish for the purpose of obtaining job advancement. If these criteria are present and can be substantiated in the event of an audit by the Internal Revenue Service, it would appear that a deduction of publication expenses under Section 162 of the Internal Revenue Code of 1954 should be allowed."

We are grateful to Allen Press for this information.

New Law on Copyright A new U.S. Copyright Law went into effect 1 January 1978. That law will affect all copyrighted journals in a number of areas, but will not affect the TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE because our journal is not copyrighted.

Although all of the implications and potential legal problems have not been resolved, several significant features of the new law must be understood by authors and editors alike. All material sent to any editor of a copyrighted journal is potentially copyrighted before it reaches publication in that journal. In order for any organization to continue the dissemination of copyrighted information by the same means it has used in the past, as well as for authors to achieve the same level of exposure, all authors are now required to take action above and beyond current customary procedures.

Basically, the new law protects only the author, and the copyright in the journal may not be totally effective. As of 1 January 1978, if a paper is subject to copyright in any journal, each author must arrange for a formal written transfer of copyright to the journal concerned. The journal will then turn back to the author all rights, except those of the journal, so that he may do with his work whatever he wishes. Suitable forms are sent to authors to sign and return to the editor. The authors retain the right to refuse.

To reiterate, the new copyright law does not apply to our journal because the Kentucky Academy of Science does not copyright its TRANSACTIONS, nor does it intend to do so in the foreseeable future.

Page Charges At the Sixty-third Annual Meeting of the Kentucky Academy of Science in November 1977 at Western Kentucky University, the membership adopted the policy of mandatory assessment of page charges for all papers published in the TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE. That charge will be $15.00 per page or portion thereof, and went into effect on 1 January 1978 with Volume 39, Numbers 1–2. The actual costs of publication are in excess of $40.00 per printed page or portion thereof, and there is need to help defray those costs if the present quality of the TRANSACTIONS is to be maintained.

Annual Dues At the Sixty-third Annual Meeting of the Kentucky Academy of Science in November 1977 at Western Kentucky University, the membership adopted the following changes in all categories of dues, effective 1 January 1978: Active Member, $10.00 per year; Student Member, $7.00 per year, not to exceed 4 years; Life Member, $100.00 as a single payment; and Institutional Affiliate, $50.00 or multiples thereof per year. Since that meeting, The University of Louisville, Morehead State University, Eastern Kentucky University, and Western Kentucky have become Institutional Affiliates. Kentucky State University and Kentucky Wesleyan College have agreed to become affiliated, and invoices have been sent to them. Several other colleges and universities have expressed an interest in affiliation, and it is hoped that all institutions of higher education in the Commonwealth will join with us in our efforts to promote science.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

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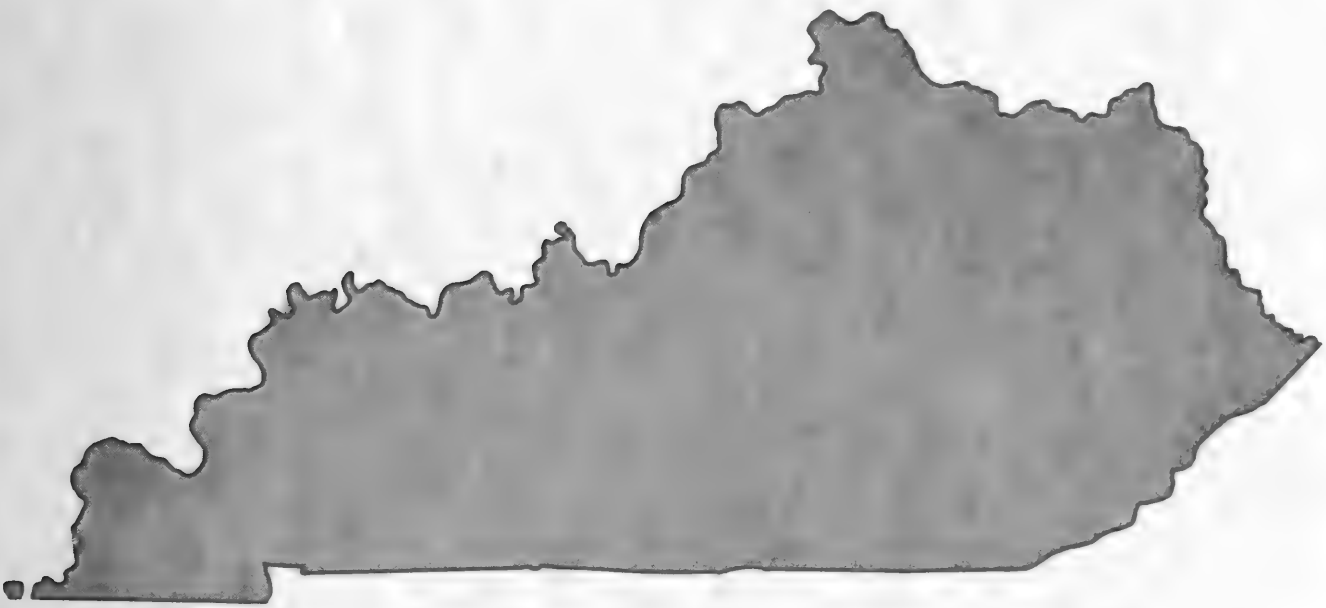

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Attitudes of Kentucky College Students Toward Science

GEORGE H. MILLER
Division of Natural Sciences, University of Louisville,
Louisville, Kentucky 40208

ABSTRACT

This study investigated some attitudes toward science of 909 upperclass students in 3 large state universities and 9 small liberal arts colleges in Kentucky in relation to selected academic and vocational characteristics. The attitudes related to support of science and the scientific enterprise, and orientation toward scientific thought and habits.

Comparisons were made of students classified as to their academic area, hours of college course work in science, type of institution attended, and sex. The possible effects on attitudes due to interactions involving those variables were also investigated. An additional series of analyses involved prospective elementary and secondary teachers and those students not choosing teaching as their vocation.

College students attending large state institutions evinced stronger support toward science than students at small liberal arts colleges, as did students with more than 18 semester hours of course work in science, and students who majored in natural science subjects. Male and female students showed no difference in their support toward science. Students pursuing nonteaching careers were more positive toward science than elementary or secondary education students.

INTRODUCTION

Never before have the sciences been so much a part of the nation's culture. We live in a scientific civilization, an environment greatly influenced by the applications of science, with the general public in many ways aware of its importance and its influence on our daily lives.

A general awareness of the importance of science does not necessarily mean its functioning as a cultural activity of man is understood or universally supported, nor can we assume the learning of factual scientific information is always accompanied by the acquisition of desirable attitudes and thought processes (Shrigley 1974). The intent of this study was to investigate some attitudes of college students in Kentucky in relation to selected academic and vocational characteristics, as they relate to support of science and the scientific enterprise, and orientation toward scientific thought and habits. The Schwirian *Science Support Scale* (Tri-S) provided a measure of the extent of support toward science and the Vitrogan *Generalized Attitude Toward Science* (VGAS) scale assessed the orientation of respondents toward scientific thought. Comparisons were made of college students classified as to their academic area, hours of college course

work in science, type of institution attended, and sex. In consideration of their potential contribution to improving the overall orientation toward and support of science through their future roles in the classroom, an additional series of analyses was made involving prospective elementary teachers, prospective secondary teachers, and students not choosing teaching as their vocation. The possible effects on attitudes due to interactions between variables were also investigated. This study was not intended to determine where or how the attitudes were acquired, but to allow comparisons between various groups, and to identify factors associated with the attitudes.

ACKNOWLEDGMENTS

The author expresses appreciation to Drs. Patricia Schwirian and David Vitrogan for their permission to use the attitude instruments employed, and to the faculty at each participating institution for their cooperation in providing access to the students involved.

RATIONALE OF THE STUDY

Science educators are in general agreement as to the objectives of science education, as indicated by *Science Education in American Schools*, the Forty-sixth Yearbook of the National Society for the Study of Education, and their Fifty-ninth Yearbook, *Rethinking Science Education*. In the latter, Hurd (1960) summarized the objectives of science instruction as (1) acquiring a background of ordered knowledge, (2) developing inquiry processes for problem solving, (3) understanding the dependence of society upon scientific achievement and the interplay of science and human affairs, (4) acquiring appreciation for the importance of science and its contribution as a human intellectual activity, (5) acquiring skills and abilities for processing information and expanding self learning, and (6) formation of attitudes conducive to the use of knowledge and methods of science.

A more recent statement of the objectives of science education by Lombard and Owen (1965) specified 5 major objectives similar to those of Hurd. However, they placed the ability to apply the methods, techniques, and rational processes of science at the top of their list. They also stated that the success of the entire scientific enterprise depends to a great extent on the general attitude of its surrounding culture. Brown (1954) and Blough (1960) have expressed similar views for the need for desirable attitudes toward science.

Science in a technological society is not unique in kind but rather in its high degree of development and wide scope. The combination of elements indispensable for modern science are not immutable, and any altering of conditions will affect the progress of science. Parsons (1951:338) noted the relationship between science and society when he stated, "Science is intimately integrated with the whole social structure and culture condition. They mutually support one another—only in certain types of society can science flourish, and conversely, without a continuous and healthy development and application of science such a society cannot function properly." According to Nagel (1959), Seaborg (1970), and Bronowski (1965), any success at improving the quality of life and achieving a fuller sense of human dignity will result from a coordinated interplay of all our sciences and our social and philosophical outlook. All those forces must be used in a healthy combination, built around a common trust and understanding.

The Scientific Literacy Research Center at the University of Wisconsin was founded to work on problems associated with knowledge in and of science needed by a population living under democratic principles. As a result of a review of the literature from 1946 to 1964 concerning scientific literacy, science for general education, science for the citizen, and science and society, Pella et al. (1966) derived a set of referents describing a scientifically literate person.

Nonspecific in nature, but nevertheless occurring in a pervasive role, a constructive attitude toward science was identified as characteristic of such a person.

The National Science Teachers Association (1968) sponsored report, *Steps Toward Scientific Literacy, A Report of College-Level Conferences on Science for Non-science Majors,* stressed attitudes, interests, values, and appreciations as vital objectives if we are to achieve a scientifically literate society. Eiss and Harbeck (1969) cautioned that simply an increased awareness of facts about science often results in a greater dislike for science; therefore, we must concern ourselves with the attitudes and values of students, and place increased emphasis on objectives in the affective domain. Until educational programs consider such objectives, they will be inadequately evaluated. An analysis of research on instructional procedures led Ramsey and Howe (1969:70) to a similar conclusion when they said, "a student's attitude toward science may well be more important then his understanding of science since his attitudes determine how he will use his knowledge."

Helping young people achieve a realistic, practical, and constructive approach to science in their lives is a task that falls mainly on science instruction in the schools (Hawn 1960, Kuhn 1973). In addition, it would appear that the most opportune conditions for either acquiring constructive thought processes and attitudes or improving existing ones would be during the formal school years. Worth (1965) and Wittlin (1963) reported that behavioral traits and personality patterns are established during the early years, and changes during later years are difficult to effect. As a vocational group, teachers are in a position to serve as models for individuals whose attitudes are often as yet ill defined. The nature of the teaching function places teachers in a situation where they are relatively free to sanction or disapprove attitudes students exhibit. This is consistent with a statement by Watson (1967) to the effect that the teacher establishes the tone or social climate within which pupil learning occurs. A common suspicion is that there is a major relationship between the characteristics of the "whole teacher" and the learning of the "whole child."

The degree of association between a teacher's attitudes and characteristics, and student outcomes in the classroom has not been resolved, but a body of literature is accumulating that indicates significant relations do occur (Bixler 1958, Rosenthal and Jacobson 1968, Hone and Carswell 1969, Washton 1971, and Rothman 1969). Therefore, it would seem appropriate, if the objectives of science education are to be accomplished, that the attitudes toward science of prospective and in-service teachers must be given special consideration.

Previous efforts to assess attitudes toward science of various segments of the population are few in number and of questionable value. One limitation has been the unavailability of suitable instruments for assessment. Another has been preoccupation, until recently, with cognitive outcomes in the schools while minimizing affective objectives.

Considerable confusion is evident in the literature concerning the distinction between the possession of scientific attitudes and positive attitudes toward science. The former refers to the possession of thought processes and skills employed in using the scientific method, while the latter should properly be reserved for the state of mind mediating one's response to a psychological object, placing it in the affective domain. Another point that needs attention is the relatively frequent equating of accuracy of perception of science and favorableness of attitude toward science. Again, the first appears to be in the cognitive domain and the latter in the affective.

An early effort to assess the opinions of college students, in relation to the nature of science and its purpose in society (Wilson 1954), showed that nearly a third of the students thought science responsible for much of the evil in the world, and approximately half were in favor of federal

control for the financing and direction of all scientific research.

Another effort to determine the college student's concepts and perceptions of science and the scientist was reported by Mitias (1970). The instrument used to gather information contained 2 incomplete statements about science and the scientist that the student was asked to complete with the first response that came to mind. Responses similar in meaning were grouped together and summarized. Mitias observed 14 categories for "science" and 10 for "the scientist," with no dominating stereotyped concept for either topic. By assigning positive, neutral, or negative character to the responses, it was found that the concept of science as "a necessary evil" ranked second in frequency, and the first positive concept of science ranked fifth. The majority of observed concepts represented a neutral view.

The image of the scientist, as perceived by college students, was reported by Beardslee and O'Dowd (1961), who used a 48-scale semantic differential instrument. Data suggested a readiness to respond to the word "scientist" in a complex manner. The image was very similar for freshmen and seniors, but there was evidence that students entering college had a more favorable view of the scientist than students who had already spent a semester in college. The strong features of the image of the scientist were his intelligence and driving concern to extend knowledge and discover truth. The weaknesses in his image related to his being out of touch with life and uninterested in people and art, and a nonconformist with only moderate control of his impulses.

Snow and Cohen (1968) explored the prestige hierarchy among senior college students toward the natural sciences, the social sciences, and the humanities, and whether it was constant or influenced by continued professional specialization. The initial testing indicated that hierarchical professional evaluation was present on the undergraduate level, with science students exhibiting the most favorable attitude toward their own major, ranking the social sciences next, and humanities last. Among the social sciences and humanities students, their own group was placed with the sciences and they relegated the other (social sciences or humanities) to the least favorable position. With continued professionalization of the students, some modification was observed. The sciences exhibited a more favorable attitude toward the humanities rather than the scoial sciences, and social science graduate students exhibited equally favorable attitudes toward all professions.

Sadava (1976) compared the attitudes toward science of nonscience majors to those of the general public, as measured previously in a national survey by the Opinion Research Corporation. The results indicated the students had more negative opinions than the general population.

Most research on attitudes of teachers toward science attempted to measure or obtain opinions concerning science as an academic subject, or toward the teaching of science. Dutton and Stephens (1963) constructed a Thurstone type instrument intended to measure attitudes toward teaching elementary science, and reported generally favorable attitudes toward teaching science among prospective elementary teachers.

Kane (1968) used the semantic differential technique to assess the attitudes of prospective elementary teachers toward mathematics, science, language arts, and social studies as academic areas and as future teaching areas. He also measured their attitudes toward "teaching children," and found a significantly higher score for "teaching children" than for teaching children any of the specific academic areas. Presumably, they conceived the role of "teaching children" apart from teaching specific subjects to them. He did not find any significant differences among the group attitudes toward the 4 academic areas.

Schwirian (1969) employed her own instrument to determine which of 8 personal and professional characteristics were

related to 191 elementary teachers' attitudes toward science. Younger teachers possessed more positive attitudes than older teachers, and graduates of state schools were more favorable to science than graduates of liberal arts colleges, as were teachers with 10 or more semester hours of science course work. She concluded that the most positive teacher would most likely be a person under 40 years of age who graduated from a state school and had taken 10 or more hours of course work in science. A follow-up study by Schwirian (1972) produced results consistent with her earlier study.

An improvement in attitudes toward science, as measured by the *Purdue Master Attitude Scale* (Siemankowski 1969), was the result of an experimental general education science course using a wide variety of audiovisual aids, programmed learning, and an autopaced teaching process. The emphasis on individualized learning, although not affecting content achievement or understanding of science, was considered useful in improving attitudes. Recent studies attempting to identify conditions that contribute to a more positive attitude of teachers toward science are those of Barufaldi et al. (1977), Johnson et al. (1974), Kennedy (1973), Shrigley (1977), and Simmons and Esler (1972).

RESEARCH PROCEDURES

In order to assess the attitudes toward science of college students in Kentucky, all degree granting colleges in the state were invited to participate and provide access to their students. Twelve schools agreed to do so: 3 large state institutions, Morehead State University, Murray State University, and the University of Louisville, and 9 small private liberal arts colleges, Asbury College, Bellarmine College, Brescia College, Cumberland College, Kentucky Wesleyan College, Pikeville College, Spalding College, Thomas More College, and Union College participated. Each school offered a teacher preparation program, and collectively represented 60 percent of the schools in the state with such a program. The state schools all had enrollments of over 7,000 students while the private schools ranged from 800 to 2,000 students. Each private school was either affiliated with a religious denomination at the time of the study or had been in its past, though none restricts admission on the basis of religion.

TABLE 1.—CHARACTERISTICS OF 441 STUDENTS AT LARGE STATE SCHOOLS AND 468 STUDENTS FROM SMALL PRIVATE SCHOOLS IN KENTUCKY

	Large state schools	Small private schools	Total
Men	191	220	411
Women	250	248	498
Humanities	114	88	202
Natural sciences	126	103	229
Social sciences	201	277	478
Elementary education	113	121	234
Secondary education	140	159	299
Nonteaching	188	188	376

A total of 909 students was involved in the study, 468 from private colleges and 441 from state institutions. Since all subjects were juniors or seniors, all had completed a similar educational objective since each school required participation in a general education program during the first 2 years of study.

To effect as representative a sample as possible, an effort was made to include both male and female students majoring in the academic areas of humanities, natural sciences, and social sciences from each school. Since each school offered a teacher preparation program, an effort was made to include candidates at both the elementary and secondary levels in the sample (Table 1). The selection process was randomized to the extent possible when working with intact groups.

Permission was obtained to use attitude assessment instruments developed by Schwirian (1968) and Vitrogan (1967). Administration and processing of the data occurred the spring semester of 1971. Responses to the instruments and a personal data page were key punched on IBM

TABLE 2.—SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS FOR STUDENTS AT SMALL PRIVATE SCHOOLS AND LARGE STATE SCHOOLS AS DERIVED BY THE TRI-S AND VGAS SCALES

Scale	Type of school	n	Mean	$\hat{\sigma}$	t
Tri-S	Small private	468	107.06	11.89	4.47[1]
	Large state	441	110.71	12.72	
VGAS	Small private	468	188.06	20.94	2.01[2]
	Large state	441	190.08	20.10	

[1] Significant at the 0.01 level.
[2] Significant at the 0.05 level.

cards for processing on an IBM 360/40 computer.

The independent or main effect variables examined as possible sources of variance in the group means were (1) type of institution (state or private liberal arts), (2) semester hours of science (0 to 8, 9 to 17, 18 or more), (3) sex, (4) academic area (humanities, social sciences, natural sciences), and (5) vocational choice (elementary education, secondary education, nonteaching). The categories for semester hours of course work in science were chosen with the intention of separating students taking the minimum possible work in science, according to academic requirements in the catalogs, and students choosing additional science courses, from the group following the more typical academic nonscience program.

Possible interaction effects on attitudes toward science were investigated with the variables (1) sex and type of institution, (2) sex and hours of course work in science, (3) sex and academic area, (4) academic area and type of institution, (5) vocational choice and hours of course work in science, (6) vocational choice and sex, and (7) type of institution and teaching level.

The statistical procedures used in determining the significance of the differences in group means for the main effect variables were the t statistic for comparisons involving 2 means, and a one-way analysis of variance where more than 2 means were examined. Where significance occurred involving 3 or more means, an additional procedure was necessary to determine which means were significantly different. The procedure employed in this study involved the computation of multiple t tests. Stratification according to the different levels of the main effects involved in the possible interactions resulted in 2×2 and 2×3 analysis of variance designs. Interactions involve specificity of effect, whereby the effect of one variable changes, depending upon the specific value of the second variable. Interaction effects are relevant to generalization statements about the main effect variables, and limitations upon generalizability appear in the statistical analysis as significant interactions.

TABLE 3.—SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS FOR MEN AND WOMEN STUDENTS AT KENTUCKY COLLEGES AS DERIVED BY THE TRI-S AND VGAS SCALES

Scale	Sex	n	Mean	$\hat{\sigma}$	t
Tri-S	Men	412	108.37	13.03	2.04[2]
	Women	497	109.16	11.97	
VGAS	Men	412	187.87	20.55	0.96
	Women	497	190.66	20.51	

[1] Significant at the 0.05 level.

TABLE 4.—ANALYSIS OF VARIANCE FOR NUMBER OF SEMESTER HOURS OF SCIENCE BY STUDENTS IN SELECTED KENTUCKY COLLEGES AS DERIVED BY THE TRI-S AND VGAS SCALES

Scale	Source of variation	Sum of squares	df	Mean square	F
Tri-S	Hours of science	5,709	2	2,854.50	19.11[1]
	Within	135,339	904	149.38	
VGAS	Hours of science	1,760	2	880.00	2.08
	Within	382,528	904	422.22	

[1] Significant at the 0.01 level.

The criterion variables employed in this study reflect attitudes toward science. As an aid in determining the degree of relationship between the 2 estimates, scores were correlated for each group in the study. The intent of the analysis was to gain additional insight into the characteristics of specific groups.

RESULTS OF ANALYSES AND DISCUSSION

Results of analyses involving the *t* test for "type of institution" (Table 2) indicate that the type of institution attended is related to attitudes toward science as measured in this study. Students attending large state schools scored significantly higher on the Tri-S and VGAS scales than students at small private colleges. The *t* value of 4.47 on the Tri-S was significant at the 0.01 level. Analyses for "sex group" (Table 3) revealed that women are oriented toward scientific thought and processes to a greater extent than men, and a lack of significant difference as to support of science, although the trend in scores did favor women over men.

The summary of the analysis of variance involving the main effect variable "semester hours of science" in relation to the Tri-S and VGAS scales is given in Table 4. With 2 degrees of freedom in the numerator and 904 in the denominator, an F value of 19.11 for the Tri-S was highly significant at the 0.01 level and was the highest of 20 such values calculated. A multiple comparison test applied to the differences between the means on the Tri-S for "semester hours of science" was used to determine which of the means were significantly different and produced the large F value in Table 4. The mean attitude score for students with 18 or more semester hours of science was significantly higher than for students with 0 to 8 or 9 to 17 hours of science. No significant difference was found in the attitude scores for students with 0 to 8 hours of science and those with 9 to 17 hours.

Therefore, students with 18 or more semester hours of science evinced greater support toward science as a cultural activity than students who followed a typical nonscience program or those who elected to take other subjects in lieu of the available general education science (Table 5).

The summary of the analysis of variance involving the main effect variable "academic area" in relation to the Tri-S and VGAS scales is shown in Table 6. The F value for the VGAS was only 0.66, while a highly significant 9.04 was obtained for

TABLE 5.—RESULTS OF THE MULTIPLE COMPARISON TEST APPLIED TO THE DIFFERENCES BETWEEN MEANS ON THE TRI-S SCALE FOR SEMESTER HOURS OF SCIENCE TAKEN BY STUDENTS AT SELECTED KENTUCKY COLLEGES

Categories compared	n	Means	*t*
0–8 hours of science	266	107.84	0.94
9–17 hours of science	404	106.94	
0–8 hours of science	266	107.84	4.55[1]
18 or more hours of science	239	112.93	
9–17 hours of science	404	106.94	6.01[1]
18 or more hours of science	239	112.93	

[1] Significant at the 0.01 level.

TABLE 6.—ANALYSIS OF VARIANCE FOR ACADEMIC AREA PREFERRED BY STUDENTS AT SELECTED KENTUCKY COLLEGES AS DERIVED BY THE TRI-S AND VGAS SCALES

Scale	Source of variation	Sum of squares	df	Mean square	F
Tri-S	Academic area	2,761	2	1,380.50	9.04[1]
	Within	138,287	904	152.63	
VGAS	Academic area	560	2	280.00	0.66
	Within	383,680	904	423.49	

[1] Significant at the 0.01 level.

the Tri-S. A multiple comparison test was applied to the differences between means on the Tri-S for the "academic area" variable to determine which categories of the variable were significantly different. Natural science majors scored considerably higher than humanities or social sciences majors (Table 7). In each instance, the difference was significant at the 0.01 level. No significant difference was found in the attitude scores for students who majored in humanities or social sciences.

The results of the analysis of variance involving "vocational choice" (Table 8) reveal the F value on the VGAS scale to be nonsignificant at 0.34, while a highly significant 14.64 was obtained for that variable on the Tri-S. A multiple comparison test applied to the differences between the means on the Tri-S scale for the "vocational choice" variable (Table 9) was used to determine which means were significantly different and contributed to the large F values in Table 8. The decision to work toward a teaching position appears to be related to the degree of support afforded science (Table 9). The mean attitude score on the Tri-S for students not working toward a teaching position was considerably higher than the means for either prospective elementary or secondary teachers. There was no difference between the attitudes of students preparing to be elementary or sceondary teachers.

The analysis also tested for first-order interactions involving specific 2-variable combinations of the main effects. No significant interactions occurred, strengthening the generalizability of the previous results and the external validity of the research findings. The variables related to attitudes toward science do no depend upon specific values of the other variables for their effects to be manifested.

Although the 2 attitude scales were related, since a correlation of responses from each group in the study resulted in r values significantly different from zero, the degree of correlation was not impressive, and it appears that they measure, for practical purposes, different dimensions of attitude toward science. Secondary education students exhibited the highest relationships between the 2 scales with an r value of 0.4026, indicating slightly over 16 percent of the variance in one scale may be attributed to variance in the other scale for that group. Although statistically significant, the relationship for students not working toward a teaching position implies a variance accountability of less than 6 percent between the scales, certainly not an impressive relationship (Table 10).

TABLE 7.—RESULTS OF THE MULTIPLE COMPARISON TEST APPLIED TO THE DIFFERENCES BETWEEN MEANS ON THE TRI-S SCALE FOR ACADEMIC AREA PREFERRED BY STUDENTS AT SELECTED COLLEGES IN KENTUCKY

Categories compared	n	Means	t
Humanities majors	202	107.58	3.52[1]
Natural science majors	230	111.77	
Natural science majors	230	111.77	3.91[1]
Social science majors	477	107.85	
Humanities majors	202	107.58	0.26
Social science majors	477	107.85	

[1] Significant at the 0.01 level.

TABLE 8.—ANALYSIS OF VARIANCE FOR VOCATIONAL CHOICE OF STUDENTS AT SELECTED KENTUCKY COLLEGES AS DERIVED BY THE TRI-S AND VGAS SCALES

Scale	Source of variation	Sum of squares	df	Mean square	F
Tri-S	Vocational choice	4,417	2	2,208.50	14.64[1]
	Within	136,631	904	150.81	
VGAS	Vocational choice	288	2	144.00	0.34
	Within	384,000	904	423.84	

[1] Significant at the 0.01 level.

The variability of the scores for the groups responding to the attitude scales was consistent in that the test of the homogeneity of variance failed to produce any significant F ratios. Indications of the dependability of the scores reported in this study may be surmised from the reliability coefficients obtained from the instruments, with respectable values of 0.7853 for the Tri-S and 0.8118 for the VGAS scale.

CONCLUSIONS AND IMPLICATIONS

Possession of sufficient semester hours of course work in science to qualify for a minor or a major was associated with a more positive attitude toward science than was true with students with fewer hours. This could be interpreted in either of 2 ways. Participation in science courses may be contributing toward a more positive attitude, or a preexisting more positive attitude may influence students to enroll in more science courses. Although reassuring to science educators, it would be presumptuous to infer that enrollment in science courses necessarily leads to improved attitudes. Until further research clarifies the situation, all that can be said is that students with a minor or a major in science also have more positive attitudes toward science. Had less positive attitudes been associated with increased course work in science, a much more serious problem would face science educators than occurs with the present situation. When the observed relation between attitudes and course work in science is better understood, and causal relations are determined, programs to improve attitudes of nonscience students will have an enhanced probability of success.

The findings of this study indicate social science and humanities majors, at both small and large institutions, possess less favorable attitudes toward science as a cultural activity of man than do natural science majors. Thus, it would appear that some of the objectives of the general education program are not being achieved. The nonscience student may be acquiring an understanding of science; that has neither been established nor disproved in this study, but it is apparent that all student groups do not exhibit an equally supportive positive attitude toward science. It may be necessary to revise or add to the currently available general education science courses in order to achieve the stated objectives more fully. Verbal and written comments from the subjects of the

TABLE 9.—RESULTS OF THE MULTIPLE COMPARISON TEST APPLIED TO THE DIFFERENCES BETWEEN MEANS ON THE TRI-S SCALE FOR VOCATIONAL CHOICE OF STUDENTS AT SELECTED KENTUCKY COLLEGES

Categories compared	n	Means	*t*
Elementary education	234	105.95	1.85
Secondary education	300	107.89	
Secondary education	300	107.89	3.48[1]
Nonteaching	375	111.26	
Elementary education	234	105.95	5.18[1]
Nonteaching	375	111.26	

TABLE 10.—CORRELATIONS BETWEEN THE ATTITUDE SCALES FOR EACH GROUP AND FOR THE TOTAL SAMPLE OF STUDENTS FROM SELECTED KENTUCKY COLLEGES. ALL CORRELATIONS ARE SIGNIFICANTLY DIFFERENT FROM ZERO AT THE 0.01 LEVEL

Group	n	r	r^2
Small private schools	468	0.3377	0.1140
Large state schools	441	0.3001	0.0901
Males	412	0.3002	0.0902
Females	497	0.3443	0.1185
Zero–7 semester hours of science	266	0.3298	0.1087
8–17 semester hours of science	404	0.3300	0.1089
18 or more semester hours of science	239	0.2981	0.0889
Humanities majors	202	0.3254	0.1058
Natural science majors	230	0.2894	0.0837
Social science majors	477	0.3375	0.1139
Elementary education	234	0.3802	0.1445
Secondary education	300	0.4026	0.1620
Nonteaching	375	0.2408	0.0579
Total	909	0.3221	0.1037

investigation frequently referred to the boring nature of current courses and their lack of relevancy. An increased emphasis on the interrelations of science, technology, and society, and more frequent investigations into contemporary problems seem warranted.

The association between attitudes toward science and the type of institution attended may be due to an inherent difference between students attending state schools and those attending private liberal arts colleges, or it may be an indication of change that occurs while attending one type of institution and not at the other. Either or both of those conditions would seem to offer the best explanation for the observed association since their general education requirements and catalog descriptions do not differ appreciably. Regardless of the source of the difference, an effort should be made to improve student attitudes toward science at the small liberal arts colleges.

One of the most rewarding experiences of this study was the opportunity to establish relations and exchange views with nonscience faculty across the state. It became apparent that members of the various disciplines share many of the same concerns and have the potential to contribute much toward the solution of our common concerns. It would seem advisable to increase contacts and communication across disciplinary lines and among schools if we are to maximize the potential.

In view of their potential contribution to improving attitudes toward science through their future roles in the classroom, the lower attitude scores of prospective teachers, as compared to students not preparing for a teaching carrer, should be regarded with concern. If teachers are to assist others in acquiring or improving existing constructive attitudes, it would seem reasonable that they themselves should first possess those attributes.

It may be worthwhile to undertake curricular revision whereby prospective elementary and secondary teachers participate in special science courses intended to encourage formation of more positive attitudes. Such courses should stress the nature of science, its interrelationship with society, and the contribution of science as a human intellectual activity along with the more conventional process and content objectives. Currently, college faculties in the state have indicated little support for science courses expressly for prospective teachers, but the results of this study indicate present programs to be inadequate.

Regardless of its final form, remedial action is warranted, the nature of which will need to be determined in subsequent research.

LITERATURE CITED

BARUFALDI, J. P., L. J. BETHEL, AND W. G. LAMB. 1977. The effect of a science methods course on the philosophical view of science among elementary education majors. J. Res. Sci. Teach. 14:289–294.

BEARDSLEE, D. C., AND D. D. O'DOWD. 1961. The college student image of the scientist. Science 133:997–1001.

BIXLER, J. E. 1959. The effect of teacher attitude on elementary children's science information and science attitude. Dissert. Abstr. 19:2531.

BLOUGH, G. O. 1960. Developing science programs in the elementary school. Pp. 119. *In* Fifty-ninth yearbook Natl. Soc. Study Educ. Part 1. Univ. Chicago Press, Chicago, Ill. 344 pp.

BRONOWSKI, J. 1965. Science and human values. Harper and Row, New York, N.Y. 119 pp.

BROWN, S. B. 1954. Science information and attitudes possessed by California elementary school pupils. J. Educ. Res. 47:551–554.

DUTTON, W. H., AND L. STEPHENS. 1963. Measuring attitudes toward science. School Sci. Math. 63:43–49.

EISS, A. F., AND M. B. HARBECK. 1969. Behavioral objectives in the affective domain. ED 028101. Natl. Sci. Teach. Ass. Washington, D.C. 49 pp.

HAWN, R. (ED.) 1960. Science in general education. W. Brown Co., Dubuque, Iowa. 591 pp.

HONE, E., AND E. CARSWELL. 1969. Elements of successful inservice education. Sci. Child. 6:24–26.

HURD, P. DEH. 1960. Science education for changing times. Pp. 34–37. *In* Fifty-ninth yearbook Natl. Soc. Study Educ. Part 1. Univ. Chicago Press, Chicago, Ill. 344 pp.

JOHNSON, R. F., F. RYAN, AND H. SCHROEDER. 1974. Inquiry and the development of positive attitudes. Sci. Educ. 58:51–56.

KANE, R. B. 1968. Use of the semantic differential technique to measure prospective elementary school teacher attitude toward mathematics and other subjects. ED 021761. Purdue Research Foundation, W. Lafayette, Ind. 66 pp.

KENNEDY, T. 1973. The effect of process instruction on changing preservice elementary teachers' attitudes toward science. School Sci. Math. 73:569–574.

KUHN, D. 1973. Value systems in life science instruction. Sci. Educ. 56:343–350.

LOMBARD, J. W., AND W. B. OWEN. 1965. Objectives of science education, compiled as a guide to the development of an assessment program in science education. Sci. Res. Ass., Inc., Chicago, Ill. 48 pp.

MITIAS, R. G. 1970. Concepts of science and scientists among college students. J. Res. Sci. Teach. 7:135–140.

NAGEL, E. 1959. Science and the humanities. Pp. 188–207. *In* Education in the age of science. B. Blanshard (Ed.). Basic Books, Inc., New York, N.Y. 302 pp.

NATIONAL SCIENCE TEACHERS ASSOCIATION. 1968. Steps toward scientific literacy; a report of college-level conferences on science for nonscience majors. ED 020144. Natl. Sci. Teach. Ass., Washington, D.C. 26 pp.

PARSONS, T. 1951. The social system. The Free Press, Glencoe, Ill. 575 pp.

PELLA, M. O., G. T. O'HEARN, AND C. W. GALE. 1966. Scientific literacy—its referents. Sci. Teach. 33:44–45.

RAMSEY, G. A., AND R. W. HOWE. 1969. An analysis of research on instructional procedures in secondary school science. Part 1—outcomes of instruction. Sci. Teach. 36:62–70.

ROSENTHAL, R., AND L. F. JACOBSON. 1968. Teacher expectations for the disadvantaged. Sci. Amer. 218:19–23.

ROTHMAN, A. I. 1969. Teacher characteristics and student learning. J. Res. Sci. Teach. 6: 340–348.

SAVADA, D. 1976. Attitudes toward science of nonscience major undergraduates: comparison with the general public and effect of a science course. J. Res. Sci. Teach. 13:79–84.

SCHWIRIAN, P. M. 1968. On measuring attitudes toward science. Sci. Educ. 52:172–179.

———. 1969. Characteristics of elementary teachers related to attitudes toward science. J. Res. Sci. Teach. 6:203–213.

———. 1972. Changing attitudes toward science: undergraduates in 1967 and 1971. J. Res. Sci. Teach. 9:253–259.

SEABORG, G. T. 1970. On the physical sciences. Pp. 31–38. *In* Science, engineering, and the quality of life. Charles Allen Thomas Science Symposium, St. Louis, Mo. 52 pp.

SHRIGLEY, R. 1974. The correlation of science attitude and science knowledge of preservice elementary teachers. Sci. Educ. 58:143–151.

———. 1977. The function of professional reinforcement in supporting a more positive attitude of elementary teachers toward science. J. Res. Sci. Teach. 14:317–322.

SIEMANKOWSKI, F. T. 1969. An auto-paced teaching process in physical science for elementary teacher preparation: a pilot study. J. Res. Sci. Teach. 6:150–156.

SIMMONS, J., AND W. ESLER. 1972. Investigating the attitudes toward science fostered by the process approach program. School Sci. Math. 72:633–636.

SNOW, A., AND L. K. COHEN. 1968. Student at-

titudes toward the sciences and the humanities. J. Educ. Res. 61:456–461.

VITROGAN, D. L. 1967. A method for determining a generalized attitude toward science. Sci. Educ. 51:170–175.

WASHTON, N. 1971. Improving elementary teacher education in science. Reprinted by D. Williams in Current research in elementary school science. The Macmillan Co., New York, N.Y. 378 pp.

WATSON, F. G. 1967. Research on teaching science. Pp. 1031–1059. *In* Handbook of research on teaching. N. L. Gage (Ed.). Rand McNally and Co., Chicago, Ill. 1218 pp.

WILSON, L. 1954. A study of opinions related to the nature of science and its purpose in society. Sci. Educ. 38:159–164.

WITTLIN, A. S. 1968. Scientific literacy begins in the elementary school. Sci. Educ. 47:331–342.

WORTH, W. H. 1965. The critical years. Canadian Administrator 5.

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Effect of Cohabitation on Survivorship of *Drosophila melanogaster* Exposed to Varying Oxygen Atmospheric Concentrations[1]

GERTRUDE C. RIDGEL AND GERRIT P. KLOEK
Department of Biology, Kentucky State University, Frankfort, Kentucky 40601

ABSTRACT

Unisexed and bisexed cultures of vestigial wing, brown-eyed *Drosophila melanogaster* were exposed to 9, 21, 33, and 49 percent oxygen atmospheric concentrations. Flies in unisexed cultures, in almost every instance, survived longer than those in cohabitation. The lethal time to 50 percent mortality was shorter in bisexed cultures exposed to high (49%) and low (9%) oxygen mixes than among flies in the unisexed cultures similarly exposed. Atmospheric mixtures of 33 percent oxygen did not appear to affect survivorship. Mean longevities in all female cultures were significantly longer than the male cultures.

INTRODUCTION

Observations of sex differences in mortality of *Drosophila melanogaster* have been observed by many investigators including Pearl and Parker (1921) and Kloek et al. (1976a). Experimental evidence in our laboratory showed that the difference was more pronounced in our vestigial wing (vg), brown-eyed (bw) strain than in our wild type. Greiff (1940) cited Krubiegel, who in 1939 reported that cohabitation of males and females shortened the mean duration of life in both sexes. Malick and Kidwell (1966) reported that single sexed cultures of their wild strain survived about 6 days longer than mated ones. Smith (1958) reported that in *D. subobscura*, mated males lived longer than mated females. However, the longevity of females could be prolonged by keeping them virgins or by exposing mating females to a high temperature for a brief period.

This investigation, a portion of a larger research program in our laboratory, was undertaken to determine the extent of differences in longevity due to cohabitation in vgbw flies when exposed to varying oxygen concentrations. All previous studies under investigation in our laboratory had been done with flies in cohabitation.

MATERIALS AND METHOD

The flies (vgbw) used in this investigation were maintained in the Kentucky State University laboratory for more than 3 years. This strain was established from the g 519 stock originally obtained from the Bowling Green University *Drosophila* Laboratory. The flies were treated with 9, 21, 33, and 49 percent oxygen concentrations in the manner described by Kloek et al. (1976a) except the designated 60-ml bottles contained males alone, females alone, or a combination of males and females. No bottle contained more than 54 flies or fewer than 31 flies. Every 5 days, the flies were etherized, counted, sexed, and placed in fresh culture medium.

RESULTS

The survivorship curves from data obtained at 5-day intervals are shown in Figs. 1–4. The shape of each curve comparing sexually isolated cultures with flies in sexual cohabitation are quite similar for a given oxygen concentration. Flies in the 21 percent oxygen concentration showed a 5-day difference in both males and females when flies of unisexed cultures were compared with those in a mixed sexed culture. The cohabitating flies exposed to 33 percent oxygen lived equally as long as those in single sexed culture for both males and

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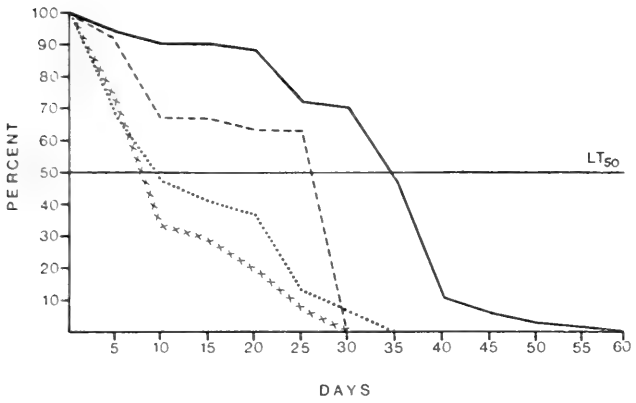

FIG. 1. Percentage of survivorship and lethal time (LT 50) of a strain of vgbw *Drosophila*, exposed to 9 percent oxygen at 5-day intervals. Solid lines represent females alone, dashed lines females in cohabitation, dotted lines males alone, and X lines males in cohabitation.

females, but at many levels during the examination periods, males living with females appeared to survive better. Unisexed male flies exposed to 49 percent oxygen had a 10-day difference in total life span compared to males in cohabitation. At the same time, the females showed a 15-day difference in life span under similar conditions. Male cultures exposed to 9 percent oxygen concentration survived 5 days longer than in bisexual cultures. Females in cohabitation survived 30 days less than those living solely with females in 9 percent oxygen (Fig. 1). However, the data for

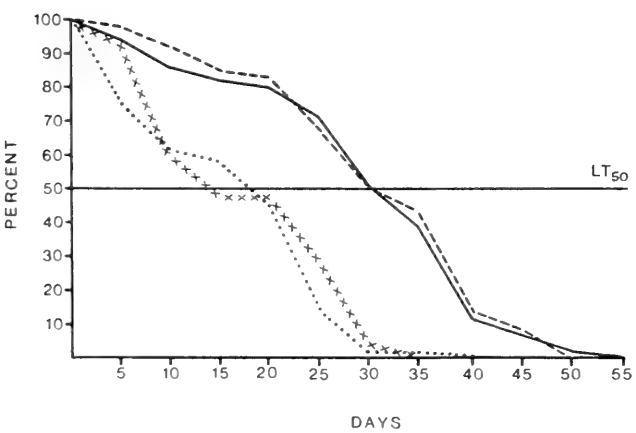

FIG. 2. Percentage survivorship and lethal time (LT 50) of a strain of vgbw *Drosophila* exposed to 21 percent oxygen at 5-day intervals. Notations are the same as in Fig. 1.

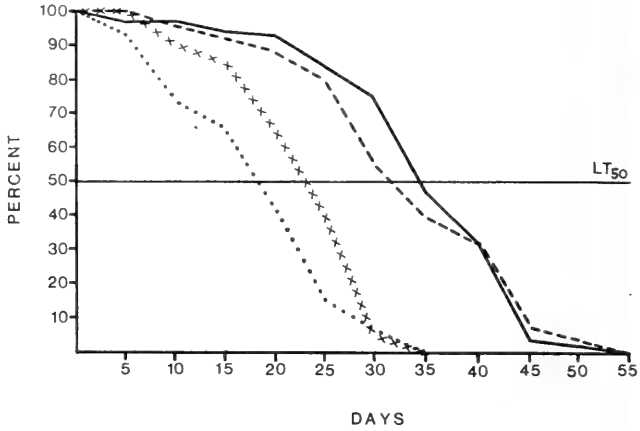

FIG. 3. Percentage survivorship and lethal time (LT 50) of a strain of vgbw *Drosophila* exposed to 33 percent oxygen at 5-day intervals. Notations are the same as in Fig. 1.

those cohabitating groups were obtained from a small sample (48 flies).

Mean longevities were determined on flies living alone and in cohabitation for each treatment. For the most part, the mean longevities were higher for flies in unisexed cultures than those in cohabitation (Table 1). The females exposed to 21 percent oxygen in cohabitation showed a slightly higher mean longevity than the single female cultures. Males in mixed sex cultures exposed to 33 percent oxygen had a higher mean longevity than those in single male cultures. When the significances of the mean were determined, the differences

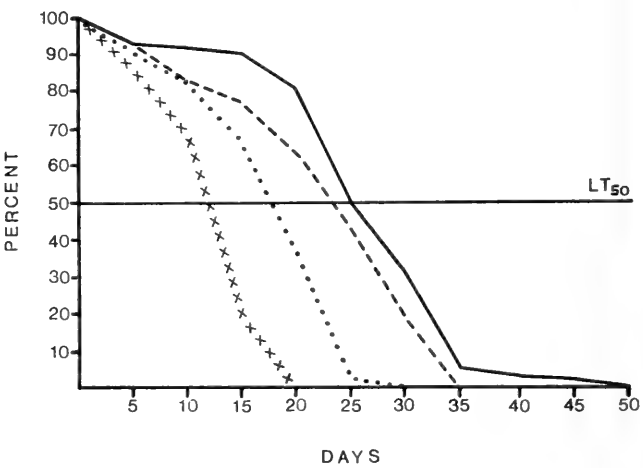

FIG. 4. Percentage survivorship and lethal time (LT 50) of a strain of vgbw *Drosophila* exposed to 49 percent at 5-day intervals. Notations are the same as in Fig. 1.

TABLE 1.—MEAN LONGEVITY (X), STANDARD DEVIATIONS (S), STANDARD ERROR, AND LETHAL TIME IN DAYS TO 50 PERCENT MORTALITY FOR VGBW FLIES EXPOSED TO 4 DIFFERENT OXYGEN ATMOSPHERES

0%	Sex	X	S	Sx	Days to 50% mortality
9	Fa[1]	33.19	11.62	1.34	39.0
	Fc[2]	23.13[3]	10.24	2.09	34.2
	Ma	15.75	10.25	1.03	9.5
	Mc	13.13	8.45	1.72	7.5
21	Fa	13.10	12.61	0.87	30.0
	Fc	32.18	11.38	1.53	30.0
	Ma	19.49	8.10	0.53	18.0
	Mc	18.89	9.47	1.41	14.0
33	Fa	36.60	16.04	2.27	34.5
	Fc	34.80	10.94	2.19	31.2
	Ma	19.75	8.36	0.84	18.0
	Mc	24.25[3]	6.94	1.55	22.5
49.9	Fa	27.50	8.91	0.59	25.0
	Fc	24.00	9.32	1.70	23.0
	Ma	19.07	6.65	0.32	17.9
	Mc	13.47[3]	4.90	0.82	12.0

[1] a = unisexed culture.
[2] c = cohabitating culture.
[3] Significant differences between a and c at 95% confidence limits.

were significant for females alone and in cohabitation when exposed to 9 percent oxygen and for males exposed to 33 and 49 percent.

The last column in Table 1 shows the days to 50 percent mortality for flies exposed to each oxygen concentration. In the 9 percent oxygen atmospheric mix, isolated females survived 39 days to 50 percent mortality, while cohabitating females lived an average of 34.2 days. In those 2 populations of female flies, the time to 50 percent mortality was actually longer than that of females exposed to 33 percent or to 21 percent oxygen mixes. Male flies in the 9 percent oxygen atmospheric mixture showed a decrease in time to 50 percent mortality of 9.5 days in isolated male cultures and 7.5 days in cohabitating cultures. Hypoxia in the males appeared more detrimental in terms of time to 50 percent mortality than hyperoxia. Males living alone that were exposed to a 49 percent oxygen atmospheric mixture had a time to 50 percent mortality of 17.9 days, while among males living with females it was 12 days.

DISCUSSION

This investigation was our initial attempt to compare the longevities of *D. melanogaster* in unisexed and bisexed cultures exposed to varying oxygen concentrations. Already reported by us (Kloek et al. 1976a) and by many others were the observations that males cohabitating had a shorter life span than cohabitating females exposed to normal and modified atmospheres. The present investigation confirmed those observations. Furthermore, the data revealed that flies in cohabitation were less tolerant when exposed to extremes in oxygen concentrations (9 and 49%) than the flies in sex isolated cultures. This finding is more clearly demonstrated when comparisons were made at the 25th day period of exposure (Table 2). In the 9 and 49 percent oxygen concentrations, cohabitating male flies did not survive as well as those in sex isolated cultures. It may be that the greater activities assumed during courting was stressful to the cohabitating organisms in hyperoxia and

TABLE 2.—PERCENTAGE SURVIVORSHIP AFTER 25 DAYS OF EXPOSURE TO 4 DIFFERENT OXYGEN ATMOSPHERES

	Oxygen Concentration (%)			
Sex	9	21	33	50
Fa[1]	72	80	84	50
Fc[2]	63	83	80	43
Ma	14	45	16	3
Mc	9	47	40	0

[1] a = unisexed culture.
[2] b = cohabitating culture.

hypoxia, and could lead to the reduced survivorship.

It appears that the 33 percent oxygen atmospheric mixture was not detrimental to the vgbw flies. This was also evident among a wild type strain in another study in our laboratory (Kloek et al. 1976b). As a matter of fact, in both investigations the flies exposed to 33 percent oxygen survived as well or better than those exposed to the 20 percent oxygen concentrations. This was unexpected since in a previous study Kloek et al. (1976a), the mean longevity of cohabitating vestigial wing brown-eyed flies exposed to 21 percent oxygen was 43.43 and 31.55 days for females and males, respectively, as compared with 32.18 and 18.89 days in the current investigation. The difference in longevity in those 2 sets of data may reflect a response to other environmental variations, including temperature. Kloek et al. (1976a) conducted their experiment January through March during which time the morning temperatures from day to day ranged from 18 to 27.5 C with an average temperature of 22.87 C over the entire experimental period. The present investigation was undertaken June through August when temperatures from day to day ranged between 24 and 27 C with an average temperature over the experimental period of 25.74 C. Siddiqui and Barlow (1972), in their research on population growth with a strain of vestigial wing flies, found that time to 50 percent mortality decreased with rising temperatures at both constant and alternating temperatures. Comparing Siddiqui and Barlow's data with ours, they found that at a constant temperature of 22.5 C the time to 50 percent mortality was 36 days and at 25 C the time was 23 days. Our data from a previous experiment (Kloek et al. 1976a) showed that with the average temperature of 22.87 C, the flies exposed to 21 percent oxygen had a time to 50 percent mortality of greater than 45 days, while in our experiment with an average of 25.74 C, the time was 30 days. Those data confirm other evidences that show that temperature differences may greatly influence experimental results in the life activities and must be considered when analyzing data on longevity of *Drosophila*.

Data presented above demonstrate clearly that males have a lethal time of 50 percent mortality far below females exposed to high (49%) and low (9%) oxygen atmospheres, and that cohabitating organisms are more affected by those exposures than sex isolated cultures. From the mean longevities and total life spans, we draw similar conclusions.

LITERATURE CITED

GREIFF, D. 1940. Longevity in *Drosophila melanogaster* and its ebony mutant in the absence of food. Amer. Nat. 74:363–376.

KLOEK, G. P., D. B. RALIN, AND G. C. RIDGEL. 1976a. Survivorship and gene frequencies of *Drosophila melanogaster*, populations in abnormal atmospheres. Aviat. Space Environ. Med. 47:272–279.

————, G. C. RIDGEL, AND D. B. RALIN. 1976b. Survivorship and life expectancy of *Drosophila melanogaster* populations in abnormal oxygen—normal pressure regimes. Aviat. Space Environ. Med. 47:1174–1176.

MALICK, L. E., AND J. F. KIDWELL. 1966. The effect of mating status, sex and genotype on longevity in *Drosophila melanogaster*. Genetics 54:203–209.

PEARL, R., AND S. PARKER. 1921. Experimental studies on the duration of life, I. Introductory discussion of the duration of life in *Drosophila*. Amer. Nat. 55:481–509.

SIDDIQUI, W. H., AND C. A. BARLOW. 1972. Population growth of *Drosophila melanogaster* at constant and alternating temperatures. Ann. Entomol. Soc. Amer. 65:993–1001.

SMITH, M. J. 1958. The genetics of longevity in *Drosophila subobscura*. Proc. Int. Cong. Genet. 2:182–183.

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Genic Variability in Some Kentucky Populations of Seventeen-Year Periodical Cicadas (Homoptera:Magicicada)

DENNIS B. RALIN AND GERRIT P. KLOEK
Department of Natural Science, Castleton State College,
Castleton, Vermont 05735

and

Department of Biology, Kentucky State University,
Frankfort, Kentucky 40601

ABSTRACT

The 17-year periodical cicadas *Magicicada cassini* and *M. septendecim* exhibited a high degree of intraspecific ($S = 0.98$) and interspecific ($S = 0.94$) genic similarity based on electrophoretic analysis of 15 protein loci. Genic heterozygosity values ($\overline{H}$) ranged from 0.076 to 0.119 in 3 populations, considerably lower than already published values for the 13-year cicadas *M. tredecassini* and *M. tredecula* (0.191 and 0.174, Krepp and Smith 1974). Adjustment for the loci not studied in common results in $\overline{H}$ values between 0.121 and 0.168 for the 4 species. The mean $\overline{H}$ value for the 4 species of periodical cicadas (0.149) is in the low range relative to the $\overline{H}$ values of *Drosophila* (0.157) and other insects (0.176). It is possible that the lower genic heterozygosities of periodical cicadas relative to other insects are a reflection of a "fine-grained" adaptive strategy resulting from the extraordinarily long subterranean nymphal stage.

INTRODUCTION

Electrophoretic analyses of structural gene loci provide direct evidence of high levels of genic variability in animal populations (Lewontin and Hubby 1966, Harris 1966, Powell 1975). Whether these electrophoretic polymorphisms are maintained by selection or are mostly neutral is a subject of continuing debate among evolutionary biologists (e.g., see Lewontin 1974). Of interest is the observation that higher levels of genic heterozygosity exist in invertebrate populations than exist in vertebrate populations (Selander and Kaufman 1973, Powell 1975). Selander and Kaufman (1973) interpreted that difference in terms of Levins' (1968) theory of adaptive strategies in relation to environmental uncertainty. That is, the greater degree of mobility and homeostatic control an organism has, the more likely it is to experience the environment as "fine-grained." Therefore, at most loci, 1 optimum allele would be selected. Small, relatively immobile organisms experience their environment as sets of alternatives in time and space, or "coarse grained." Selection in those organisms would favor different genotypes at many loci to allow for maximum fitness under different circumstances. A higher genic heterozygosity would be expected in such populations.

Although nearly 100 different animal species, subspecies, and semispecies have been examined (Powell 1975), we believe that a general theory relating physiological ecology and life history to the genetics of animal populations is still problematical. There has been no clear comparison of eurythermal and stenothermal poikilotherms, between hemimetabolic and holometabolic insects, between very large and small homeotherms, and so forth. Moreover, the vast majority of terrestrial invertebrates studied thus far are insects, and most of them belong to the genus *Drosophila*. The periodical cicadas are of interest from this point of view, since they are hemimetabolic insects having an un-

usually long generation time. Moreover, 99 percent of that time is spent in the nymphal stage in a subterranean habitat. Compared with other insects, cicadas face relatively constant conditions during the major portion of their life cycle. We decided to examine genic variability in 2 species of 17-year periodical cicadas when a brood emerged in Kentucky in 1974. In this report, we compare levels of heterozygosity in 17- and 13-year cicadas (Krepp and Smith 1974) and compare their mean heterozygosity levels with those of other insects.

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MATERIALS AND METHODS

Seventy-nine periodical cicadas were collected on 29 May and 2 June 1974. Forty-five were collected in Frankfort, Franklin County, Kentucky, and 34 were collected on the Frank Clark Farm, 3.2 km south of Monterey, Owen County, Kentucky. According to the emergence times given by Alexander and Moore (1962), they were 17-year cicadas of Brood XIV. Only 1 of the 3 17-year cicadas, *M. cassini*, is found in the Frankfort area (Alexander and Moore 1962). All 45 individuals from Frankfort had similar songs and morphology. In the Monterey area, 20 of the cicadas collected had the same morphology and the same song (a series of ticks followed by a buzz). The other 14 cicadas collected at Monterey had a distinctly lower-pitched song without any ticks in it, were noticeably larger than *M. cassini*, had reddish-yellow pronota and prothoracic pleura, reddish abdominal sternites and were identified as *M. septendecim*.

Cicadas were placed in individual 16 × 70-mm vials and covered with a 2 percent phenoxyethanol-0.25 M sucrose solution. Vials were kept in a cold room between 0–5 C for 2 weeks, and later stored at –40 C for 10 months before runs were made.

Horizontal electrophoresis was performed on 11 percent starch gels (Lot No. 371, Hiller Electrostarch Co., P.O. Box 1294, Madison, Wisconsin). Four different buffer systems were used: (1) system A of Steiner and Johnson (1973); (2) tris-citrate (pH 6.7) of Selander et al. (1971); (3) system C of Steiner and Johnson (1973); and (4) tris-maleate of Selander et al. (1971). Stain recipes were similar to those of Selander et al. (1971) and Steiner and Johnson (1973). Enzymes and proteins stained for on each buffer system were as follows: (1) aldolase (ALD), esterases (EST), general proteins (PT), indophenol oxidase/tetrazolium oxidase/superoxide dismutase (SOD), leucine aminopeptidase (LAP), malate dehydrogenase (MDH), malic enzyme (ME), 6-phosphogluconate dehydrogenase (6-PGD), phosphoglucose isomerase (PGI), and phosphoglucomutase (PGM); (2) glutamate oxaloacetate aminotransferase (GOT), glyceraldehyde-3-phosphate dehydrogenase (G-3-PDH), MDH, ME, and PGM; (3) α-glycerophosphate dehydrogenase (α-GPD), glucose-6-phosphate dehydrogenase (G-6-PD), and G-3-PDH; and (4) xanthine dehydrogenase (XDH), G-6-PDH, α-GPD, GOT, and PGI.

When more than 1 set of bands were seen on a gel slice, the most anodal set was designated 1 and the others were numbered in accordance with their distance from the anode. When a set of bands gave evidence of allelic variation, the allele of greatest anodal mobility was designated 100, and the others were designated by their mobilities relative to the 100 allele. Cathodally migrating alleles were denoted by a minus sign preceding the relative mobility.

RESULTS AND DISCUSSION

Allelic forms at consistently scorable protein loci are given in Table 1. Heterozygote banding patterns at polymorphic loci were similar to those described for

TABLE 1.—ALLELES AND ALLELIC FREQUENCIES[1] AT 15 LOCI IN 2 SPECIES OF 17-YEAR CICADAS

Locus	Homolog in 13-year cicadas[2]	*M. cassini*[1]	*M. septendecim*
PT-2	*PT-1*	100 (1.00)	100 (1.00)
PT-4	*PT-2*	100 (1.00)	100 (1.00)
SOD-1	*IPO-1*	100 (1.00)	100 (1.00)
EST-1	*ES-1*	100 (1.00)	100 (1.00)
EST-2	*ES-2*	100 (0.548), 94 (0.317), 91 (0.135)	100(0.321), 94(0.536), 91 (0.143)
EST-4	Not done	–100 (0.890), –71 (0.094), –42 (0.016)	–100 (0.464), –71 (0.250), –42 (0.286)
ME-1	*MDH-2*	100 (1.00)	100 (1.00)
PGI-3	*PGI-1*	–100 (1.00)	–100 (1.00)
PGM-1	*PGM-1?*	100 (0.205), 89 (0.491), 79 (0.304)	100 (0.071), 89 (0.750), 79 (0.179)
G-3-PDH-1	Not done	100 (1.00)	100 (1.00)
MDH-1	*MDH-1*	100 (1.00)	100 (1.00)
MDH-2	*MDH-3*	–100 (1.00)	–100 (1.00)
ALD-1	Not done	100 (1.00)	100 (1.00)
GOT-1	*GOT-1*	100 (1.00)	100 (1.00)
GOT-2	*GOT-2*	–100 (1.00)	–100 (1.00)

[1] Frequencies calculated as unweighted averages of 2 populations.
[2] From descriptions given by Krepp and Smith (1974).

13-year cicadas by Krepp and Smith (1974). Probable homologous loci are also noted in Table 1. The Frankfort population of *M. cassini* was in Hardy-Weinberg equilibrium at each polymorphic locus as tested by chi square analysis.

Genic similarities as measured by Rogers' (1972) coefficient of genic similarity are $S = 0.94$ for the heterospecific comparison and $S = 0.98$ for the conspecific comparison. Mean genic heterozygosity ($\overline{H}$) for each species population, based on 15 loci, is given in Table 2. Values calculated by actual count match quite closely with estimated values calculated from Hardy-Weinberg heterozygote frequencies. There were no significant differences among the 3 populations.

Although slightly higher than average genic similarities between conspecific populations of other organisms, the S value of 0.98 between the Monterey and Frankfort populations of *M. cassini* is still well within the range of values observed in earlier studies (Avise 1976). The S value of 0.94 between *M. cassini* and *M. septendecim* is in the high range for an interspecific comparison, reflecting the fact that all periodical cicadas are sibling species differentiated by minor morphological differences and acoustic behavior (Alexander and Moore 1962). Hardy-Weinberg estimates of genic heterozygosity in 2 species of 13-year cicadas and 2 species of 17-year cicadas are given in Table 3. The column headed $\overline{H} \pm 2$ SE seems to indicate signifi-

TABLE 2.—MEAN GENIC HETEROZYGOSITIES ($\overline{H}$) ± 2 STANDARD ERRORS IN 2 SPECIES OF 17-YEAR PERIODICAL CICADAS

Species	Population	N	$\overline{H} \pm 2$ SE (Actual Count)	$\overline{H}$ (Estimated)
M. cassini	Frankfort	45	0.098 ± 0.018	0.093
	Monterey	20	0.076 ± 0.017	0.076
M. septendecim	Monterey	14	0.119 ± 0.028	0.119

TABLE 3.—ESTIMATED GENIC HETEROZYGOSITY VALUES ($\overline{H}$) IN 4 SPECIES OF PERIODICAL CICADAS

Species	No. of Populations	No. of Loci	$\overline{H} \pm 2$ SE	Adjusted H[2]
M. tredecassini	2	15	0.191 ± 0.024[1]	0.168
M. tredecula	2	15	0.174 ± 0.033[1]	0.154
M. cassini	2	15	0.093 ± 0.012	0.121
M. septendecim	1	15	0.119 ± 0.028	0.151

[1] Calculated from given allele frequencies (Krepp and Smith 1974); Standard errors from actual counts.
[2] See text for details.

cantly lower levels of genic heterozygosity in 17-year cicadas compared with 13-year cicadas.

According to the compilations of Powell (1975), the mean heterozygosities of our brood are in the low range for those invertebrate organisms reported. Krepp and Smith (1974) sampled what were thought to be 2 species of 13-year cicadas of Brood XIX (presumably *Magicicada tredecassini* and *M. tredecula*), and found levels of genic heterozygosity in the high range for insects.

The apparent difference in the studies probably is, in part, an artifact caused by a difference in the loci sampled. We believe that 12 of the loci sampled here are homologues of those sampled by Krepp and Smith (1974). Unfortunately, their samples had already been discarded by the time we were aware that someone else had studied periodical cicadas (M. H. Smith pers. comm.). One additional highly polymorphic locus sampled by Krepp and Smith (1974), *ES-3*, seems to be comparable to our highly polymorphic *EST-4* (Table 1). We were unsuccessful in sampling 2 polymorphic loci in *M. tredecassini*–M. *tredecula*, *α-GPDH-1*, and *G-6-PDH-1* (Krepp and Smith 1974). On the other hand, we also sampled 2 monomorphic loci not sampled by them, *ALD-1* and *G-3-PDH-1* (Table 1).

In an attempt to pool these data to get an $\overline{H}$ value reflecting the greatest number of loci available at this time, we calculated an adjusted $\overline{H}$ for each species. We took the highest heterozygosity values for *G-6-PDH-1* and *α-GPDH-1* in *M. tredecassini-M. tredecula* (respectively, 0.495 and 0.280 Krepp and Smith 1974) and used them to adjust *M. cassini* and *M. septendecim* upward; and we took the 0.000 heterozygosity values for *ALD-1* and *G-3-PDH-1* (Table 1) and used them to adjust *M. tredecula* and *M. tredecassini* downward. The resultant adjusted $\overline{H}$ values (Table 3) are considerably more alike, ranging from 0.121 to 0.168. Mean $\overline{H}$ value for the unadjusted figures was 0.144 and the mean adjusted $\overline{H}$ value was 0.149. Either of those figures is in the low range compared with mean $\overline{H}$ values of *Drosophila* and other insects. Mean $\overline{H}$ values of periodical cicadas, *Drosophila*, and other insects are compared in Table 4.

Mean values for the latter 2 categories probably are significantly underestimated. The *Drosophila* value includes a number of $\overline{H}$ values for isolated semispecies, subspecies, and island populations that are lower than the values of continental populations or populations from the main species range. The other insects category includes island populations of the homop-

TABLE 4.—MEAN HETEROZYGOSITY ESTIMATES FOR SELECTED GROUPS OF INSECTS

Grouping	No. of taxa	Mean heterozygosity ± SE
Periodical cicadas	4	0.149 ± 0.008
Drosophila[1]	38	0.157 ± 0.009
Other insects[2]	10	0.176 ± 0.020

[1] Taken from Powell (1975), including all species, semispecies, subspecies, and island populations.
[2] Eight species from Powell (1975) plus 2 species from McKechnie et al. 1975.

teran *Philaenus spumarius* that have a very low $\overline{H}$ value (0.076, Saura et al. 1973). Although more data for both periodical cicadas and other insects are needed, it does appear that $\overline{H}$ values of periodical cicadas are in the low range relative to other insects in general.

Additional data may raise the mean $\overline{H}$ value for cicadas back towards Krepp and Smith's (1974) figures, or they may lower its mean even more. We believe the latter will be true. Krepp and Smith (1974) attributed their results to the high environmental uncertainty they believed those insects face. In other words, they implied that periodical cicadas experience the environment as "coarse-grained" in the terms of Levins' (1968) model of adaptive strategies.

It is difficult for us to accept Krepp and Smith's (1974) view. The insects spend more than 99 percent of their life in a subterranean habitat, and physical factors are exceedingly stable there. Therefore, we suggest that periodical cicadas perceive their environment as "fine-grained" in terms of Levins' (1968) model.

We believe that these types of analyses should prove useful in elucidating the genetic bases of environmental adaptation. We also believe it is premature to assign definitive adaptive significance to heterozygosities at this time because more loci must be examined and more species studied. For that reason, we wish to present our results here, and point out that these additional data lower the mean heterozygosity for periodical cicadas below those of *Drosophila* and other insects.

SUMMARY

The 17-year periodical cicadas *Magicicada cassini* and *M. septendecim* exhibited a high degree of intraspecific ($S = 0.98$) and interspecific ($S = 0.94$) genic similarity based on electrophoretic analysis of 15 protein loci. Genic heterozygosity values ($\overline{H}$) ranged from 0.076 to 0.119 in 3 populations, considerably lower than already published values for *M. tredecassini* and *M. tredecula* (0.191 and 0.174 Krepp and Smith 1974). Adjustment for the loci not studied in common results in $\overline{H}$ values between 0.121 and 0.168 for the 4 species. The mean $\overline{H}$ value for 4 species of periodical cicadas is in the low range relative to the $\overline{H}$ values of *Drosophila* and other insects. This is consistent with the hypothesis that periodical cicadas experience the environment as "fine-grained" and are less subject to the effects of balancing selection than are other insects.

LITERATURE CITED

ALEXANDER, R. D., AND T. E. MOORE. 1962. The evolutionary relationships of 17-year and 13-year cicadas, and three new species. (Homoptera Cicadidae, Magicicada). Misc. Publ. Mus. Zool., Univ. Mich. 121:1–59.

AVISE, J. E. 1976. Genetic differentiation during speciation. Pp. 106–122. *In* F. J. Ayala (Ed.). Molecular Evolution. Sinauer Assoc. Inc. Sunderland, Mass. 277 pp.

HARRIS, H. 1966. Enzyme polymorphism in man. Proc. Roy. Soc. Lond. B. 164:298–310.

KREPP, S. R., AND M. H. SMITH. 1974. Genic heterozygosity in the 13-year cicada, *Magicicada*. Evolution 28:396–401.

LEVINS, R. 1968. Evolution in changing environments. Princeton University Press, Princeton, N.J. 120 pp.

LEWONTIN, R. C. 1974. The genetic basis of evolutionary change. Columbia Univ. Press, New York, N.Y. 346 pp.

————, AND J. L. HUBBY. 1966. A molecular approach to the study of genic heterozygosity in natural populations. II. Amount of variation and degree of heterozygosity in natural populations of *Drosophila pseudoobscura*. Genetics 54:595–609.

MCKECHNIE, S. W., P. R. EHRLICH, AND R. R. WHITE. 1975. Population genetics of Euphydryas butterflies. I. Genetic variation and the neutrality hypothesis. Genetics 31:571–594.

POWELL, J. R. 1975. Protein variation in natural populations of animals. Pp. 79–119. *In* T. Dobzhansky, M. K. Hecht, and W. C. Steers (Eds.), Evolutionary Biology, Volume 8. Plenum Publ. Corp., N.Y. 387 pp.

ROGERS, J. S. 1972. Measures of genetic similarity and genetic distance. Studies in Genetics VII. Univ. Texas Publ. 7213:145–153.

SAURA, A., O. HALKKA, AND J. LOKKI. 1973. Enzyme gene heterozygosity in small island populations of *Philaenus spumarius* (L.) (Homoptera). Genetics 44:459–473.

SELANDER, R. K., AND D. W. KAUFMAN. 1973.

Genic variability and strategies of adaptation in animals. Proc. Natl. Acad. Sci. 70:1875–1877.

———, M. H. SMITH, S. Y. YANG, W. E. JOHNSON, AND J. B. GENTRY. 1971. Biochemical polymorphism and systematics in the genus *Peromyscus*. I. Variation in the old-field mouse (*Peromyscus polionotus*). Studies in Genetics VI. Univ. Texas Publ. 7103:49–90.

STEINER, W. W. M., AND W. E. JOHNSON. 1973. Techniques for electrophoresis of Hawaiian *Drosophila*. Island Ecosystems Integrated Res. Prog., U.S. Int. Biol. Prog., Technical Report No. 30:1–21.

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Removal of Nitrogen and Sulfur from Coal-Derived Liquids

Tay-Yean Lin and Norman L. Holy
Department of Chemistry, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Substantial amounts of the nitrogen can be removed from a variety of coal-derived liquids by extraction with sulfuric acid. The greater the concentration of sulfuric acid, the greater the amount of nitrogen removed. From the extraction characteristics, the nature of the nitrogen appears to span the spectrum between basic and neutral compounds. The sulfur content was not substantially altered by extraction with sulfuric acid. Liquid chromatography of the coal liquids also resulted in appreciable diminution of the nitrogen content; the sulfur content was unchanged. A variety of coal-derived liquids was found to respond similarly to both acid extraction and column chromatography.

Introduction

One of the obstacles to broader utilization of coal-derived liquids is the presence of fairly high levels of nitrogen in those products. High nitrogen concentrations have a very negative effect upon the possible applications of those products as fuels. Coal liquids can be used as fuels by power generating plants or other industries that can scrub out the nitrogenous by-products, but those fuels generally cannot replace fuel oils or gasoline. Refinement of coal liquids is often not feasible because nitrogen has a negative effect upon the performance of refinery catalysts (Cady and Seeling 1952, Dineen et al. 1958, Jensen et al. 1971). If coal-derived liquids are to become viable fuels for a variety of applications, it is necessary to reduce the nitrogen levels substantially.

The level of sulfur in coal liquids is not high because the liquefaction processes remove most of it. Further reduction is still desirable.

Efforts to reduce the level of nitrogen in coal-derived liquids have focused upon catalytic hydrogenation with concomitant conversion of nitrogen to ammonia, that is then scrubbed out. Hydrogenation, while effective in removing more than half the nitrogen, does require severe conditions (Schulman 1973, Vernon and Pennington 1973, Satchell 1976, Crynes 1976, Katzer et al. 1976, Stein et al. 1977). From the standpoint of economics, it would be desirable to find alternative approaches.

We sought a very simple, inexpensive method by which nitrogen and sulfur could be removed. We are aware of successful efforts to reduce nitrogen contents of shale oil by extraction with sulfuric acid (Mapstone 1948) and column chromatography (Bond and Harriz 1957). Even with that history, there was no assurance that such methods would be successful for coal liquids because the nature of the nitrogen and sulfur compounds is largely uncharacterized. Furthermore, considering that coal liquids are composed of substantial proportions of aromatic compounds, there was the distinct possibility that treatment with sulfuric acid could actually increase the sulfur content.

The nitrogenous compounds in shale oil have been characterized, in part, by their responsiveness to extraction by sulfuric acid (Mapstone 1948). By that technique, it has been possible to determine, very roughly, the proportions of basic nitrogen compounds and those that are neutral. It is attractive to make a similar study of coal-derived liquids and to compare the results with those obtained for shale oil. Additionally, few comparisons between the various coal liquids produced in several laboratories are available. There is no a priori reason to surmise that those

TABLE 1.—SULFUR AND NITROGEN CONTENTS OF COAL-DERIVED LIQUIDS[1] UPON TREATMENT WITH SULFURIC ACID

Entry	Origin	Treatment	Volume coal liquid (ml)		Total sulfur (%)	Total nitrogen (%)
			Before treatment	After treatment		
1a	GU 145 R Product #38 Gulf Oil Company	None			0.38	1.22
1b	GU 145 R Product #38 Gulf Oil Company	5% H_2SO_4 (3 ml)	5.0	4.1	0.68	0.83
1c	GU 145 R Product #38 Gulf Oil Company	50% H_2SO_4 (3)	5.0	4.0	0.76	0.83
1d	GU 145 R Product #38 Gulf Oil Company	90% H_2SO_4 (3)	5.0	3.8	0.43	0.55
1e	GU 145 R Product #38 Gulf Oil Company	100 g alumina			0.40	0.74
2a	Hydro-Oil 230 × 470 C	None			0.094	0.41
2b	Hydro-Oil 230 × 470 C	50% H_2SO_4 (3)	5.0	4.1	0.15	0.18
2c	Hydro-Oil 230 × 470 C	90% H_2SO_4 (3)	5.0	3.8	0.14	0.03
2d	Hydro-Oil 230 × 470 C	100 g alumina			0.097	0.07
3a	LO-366 400–650 F	None			0.093	0.42
3b	LO-366 400–650 F	5% H_2SO_4 (3)	5.0	4.8	0.085	0.15
3c	LO-366 400–650 F	50% H_2SO_4 (3)	5.0	4.4	0.10	0.12
3d	LO-366 400–650 F	90% H_2SO_4 (3)	5.0	4.0	0.075	0.02
3e	LO-366 400–650 F	100 g alumina			0.067	0.075
4a	LO-367 650–975 F	None			0.12	0.72
4b	LO-367 650–975 F	90% H_2SO_4 (2)	25.0	18.5	0.069	0.12
4c	LO-367 650–975 F	90% H_2SO_4 (4)	25.0	18.0	0.084	0.08
4d	LO-367 650–975 F	90% H_2SO_4 (5)	25.0	17.5	0.11	0.05
4e	LO-367 650–975 F	90% H_2SO_4 (10)	25.0	17.0	0.13	0.08
4f	LO-367 650–975 F	100 g alumina			0.12	0.21

[1] Key to Figures and Tables.

Producer	Conoco	Hydrocarbon Research	Gulf
Samples	Liquefaction Solvent	H-Coal, 180–380 F	GU 145 R, 193 C
	Hydro-Oil	H-Coal, LO-366	Product #38
	Low-Ash Extract	H-Coal, LO-367	GU 145 R, Product #38

products would respond similarly to either acid extraction or column chromatography simply because they are obtained by diverse methods. An investigation into comparisons between those fuels is timely.

ACKNOWLEDGMENTS

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EXPERIMENTAL PROCEDURES

Extraction

Data (Table 1) were obtained by adding the indicated amount of acid to a separatory funnel or centrifuge tube containing the indicated volume of coal liquid. After shaking, the layers were separated (2,000 rpm, 2 min for centrifuged samples), and the organic layer was washed with water, dried over anhydrous sodium sulfate, and filtered. Centrifugation was necessary for samples extracted with acid less concentrated than 50 percent sulfuric acid.

Chromatography

Data (Table 1) were obtained by eluting 20-ml samples of coal liquid from a 40 × 2-cm alumina column (100 g Al_2O_3, Matheson, Coleman, and Bell, 80–325 mesh) with ethyl ether. The ether was then evaporated on a rotary evaporator. Elemental analyses were performed by the Materials Analysis Laboratory, Institute for Mining and Minerals Research or Galbraith Laboratories, Knoxville, Tennessee.

A sample of coal-derived liquid was placed on a 40 × 2-cm alumina column (100 g, Matheson, Coleman, and Bell, 80–325 mesh). No solvent was employed, but a vacuum was necessary in order that the samples would pass through the column at a reasonable rate. Ten 2-ml portions were collected. The column was then washed with 100 ml of 20 percent sulfuric acid, then 100 ml of 95 percent ethanol, and, finally, 100 ml of ethyl ether. Then another 10 samples were collected. These latter fractions constituted those classified as acid washed.

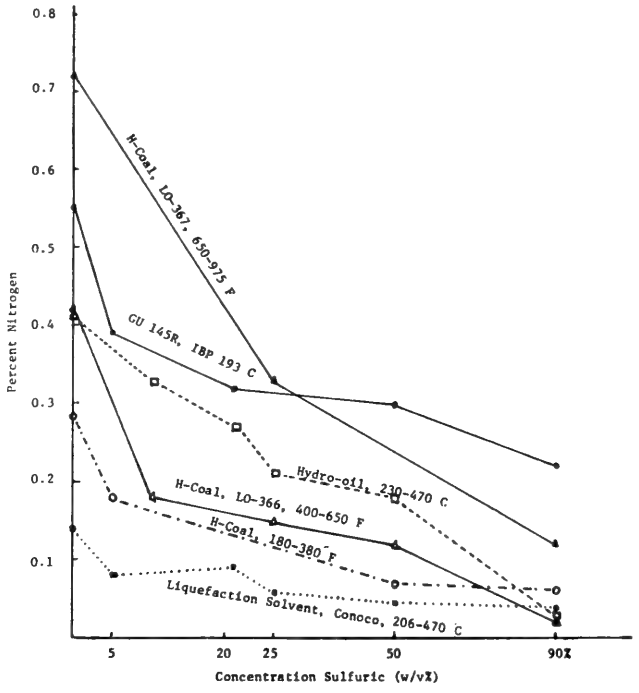

FIG. 1. Extraction of nitrogen from coal liquids with sulfuric acid.

RESULTS AND DISCUSSION

Extraction

The results of extraction of a variety of coal-derived liquids indicate that (Figs. 1, 2, 3; Table 1): (1) reduction in the nitrogen content of all coal-derived liquids tested occurred upon treatment with sulfuric acid. The curves display gross similarities though the extent of nitrogen

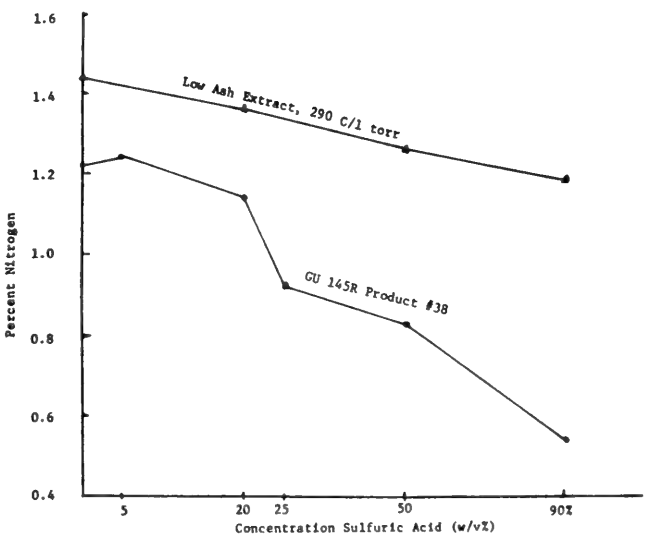

FIG. 2. Extraction of nitrogen from coal liquids with sulfuric acid.

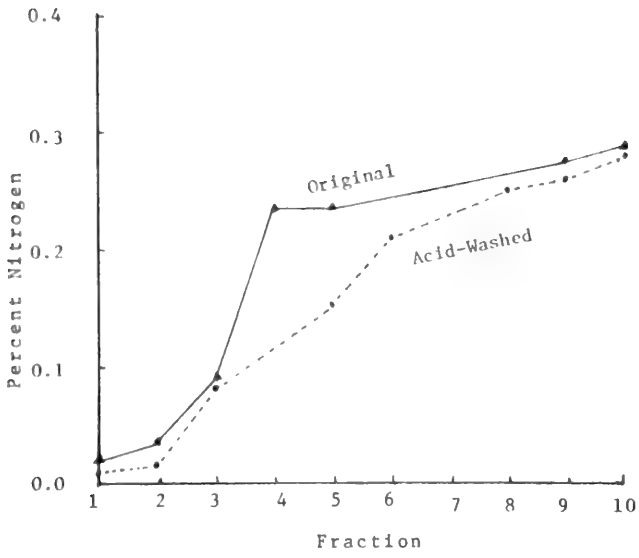

FIG. 3. Chromatography of H-Coal: light distillate 400–650 F. Original sample 0.42% nitrogen.

removal varied substantially with the sample; (2) the major amount of nitrogen can be removed from a sample by a single extraction with 90 percent sulfuric acid; (3) many different nitrogenous compounds must be present because the curves display no very distinct breaks. Therefore, a wide range of such compounds are present that span the spectrum of basic-to-neutral compounds. Shale oil displayed a much more distinct break (Mapstone 1948) at 20–30 percent sulfuric acid, and is considered to mean that there is a reasonably high concentration of highly basic nitrogenous compounds in shale oil. In contrast, coal liquids appeared to contain a lesser proportion of highly basic compounds; (4) considerable similarities were present in the nitrogenous compounds regardless of the physical characteristics or process origin as shown by the similar shapes of the curves. It should not be interpreted that the compounds were the same, but rather that there were relatively constant proportions of basic compounds or neutral compounds from one sample to another.

Recoveries varied from 65 to 98 percent after extraction, depending upon the concentration, and to some extent, the amount of acid. The more concentrated the acid, the less the material recovered. It is likely that with increasing concentration of acid there is increased tendency for it to extract phenols or other heteroatom containing molecules. Extraction of highly viscous products is not attractive; when the acid is added, the samples (e.g., GU 145 R 249 C, Gulf; Low-Ash Extraction 290 C/1 torr, Conoco; Coal Oil 3174-35, Universal Oil Products) became virtually solids, and attempted separation using centrifugation at 3,000 rpm did not result in a separation of layers.

Extraction of the sulfur compounds was not very effective (Table 1); actually, that observation paralleled that for shale oil. It is interesting to note, however, that the sulfur content did not actually increase significantly. Conceivably, sulfonation of phenolic or other derivatives could have led to higher values for sulfur.

Chromatography

Chromatography is effective in removing nitrogenous compounds from coal-derived liquids. From the data in Fig. 3, it can be seen that chromatography resulted in a substantial nitrogen reduction. That graph is typical of those obtained for several other coal-derived liquids. There are no distinct breaks in the curves, again indicating the presence of a variety of nitrogen products having different alumina affinities. It is also interesting that the columns can be regenerated rather easily; in fact, the regenerated columns actually gave better performance than the original alumina.

LITERATURE CITED

BOND, G. R., JR., AND C. G. HARRIZ. 1957. Determination of trace amounts of total nitrogen in petroleum distillates. Anal. Chem. 29:177–180.

CADY, W. E., AND H. S. SEELING. 1952. Composition of shale oil. Ind. Eng. Chem. 44: 2636–2641.

CRYNES, B. L. 1976. Catalysts for upgrading coal-derived liquids. ERDA Energy Res. Abst. 1(5):673.

DINEEN, G. U., G. L. COOK, AND H. B. JENSEN. 1958. Estimation of the types of nitrogen compounds in shale-oil gas oil. Anal. Chem. 30:2026–2030.

JENSEN, H. B., R. E. POULSON, AND G. L. COOK. 1971. Characterization of the saturates and olefins in shale-oil gas oil. Prepr. Amer. Chem. Soc. Div. Fuel Chem. 15(1):113–121.

KATZER, J. R., B. C. GATES, J. H. OLSON, H. KWART, AND A. B. STILES. 1976. Kinetics and mechanism of desulfurization and denitrogenation of coal-derived liquids. ERDA Energy Res. Abst. 1(5):673–674.

MAPSTONE, G. E. 1948. Nitrogen in oil shale and shale oil. J. Proc. Soc. New South Wales 79:135–144.

SATCHELL, D. P. 1976. Development of a process for producing an ashless low-sulfur fuel from coal. ERDA Energy Res. Abst. 1(5): 673.

SCHULMAN, B. L. 1973. Hydrogen purification and recycle in hydrogenating heavy mineral oils. U.S. (Exxon) 3,717,571.

STEIN, T. R., S. E. VOLTZ, AND R. B. CALLEN. 1977. Upgrading coal liquids to gas turbine fuels. 3. Exploratory Process Studies. Ind. Eng. Chem., Prod. Dev. Res. 16:61–73.

VERNON, L. W., AND R. E. PENNINGTON. 1973. Hydrotreating of hydrocarbonaceous liquids with carbon monoxide-containing gas. U.S. (Exxon) 3,719,588.

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Aspects of Photoperiodic Time Measurement in the Crayfish *Orconectes immunis*

E. Lynn Talton[1] and Rudolph Prins
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Experiments were conducted to determine if an hourglass model is a mechanism whereby photoperiodic time is measured by the crayfish *Orconectes immunis*. Two experiments were conducted in each of which there were 2 series of treatments. Series I and II were time (T) experiments in which T was the total length of the light–dark cycle. In Series I, the light phase of the cycle was held at 16 hours with varied lengths of darkness (LD 16;2, T 18: LD 16;8, T 24: LD16;20, T 36: LD16;32, T 48). In Series II, the dark phase was 8 hours and the hours of light were varied (LD 2;8, T 10: LD 16;8, T 24: LD 28;8, T 36: LD 40;8, T 48). No significant differences were found in the molting responses of the crayfish to the photoperiods in those experiments. The data would then indicate than an hourglass mechanism is not utilized to measure photoperiod under the conditions tested.

Introduction

Environmental factors such as temperature and photoperiod have been shown to affect molting in crayfish (Aiken 1969; Armitage et al. 1973; Mobberly 1963; Rice and Armitage 1974; Stephens 1955; Molley 1974, unpublished master's thesis, Western Kentucky University, Bowling Green, Kentucky; Sadewasser 1974, unpublished master's thesis, Western Kentucky University, Bowling Green, Kentucky; and Van Hoff 1976, unpublished master's thesis, Western Kentucky University, Bowling Green, Kentucky. Molley (unpublished thesis) and Sadewasser (unpublished thesis) have shown that crayfish respond linearly to temperature in that molting frequency increases with increases in temperatures, within limits. Temperatures fluctuate considerably during seasonal changes in temperate regions. Photoperiod progressively increases from a winter minimum daylength to a summer maximum daylength, thence cycling back to a winter minimum. Because of that predictability, photoperiod may be a more reliable environmental cue for the crayfish.

It has been demonstrated in plants and insects that a biological clock measures a time interval of the photoperiod (light or darkness) (Bowen and Skopik 1976, Hamner 1960, Lees 1966, Pittendrigh and Minis 1964, Went 1960). It is possible that crayfish (Crustacea) also use such a device. Various authors have reported that long-day photoperiods will produce higher molting frequencies than will short or normal day photoperiods (Aiken 1969, Armitage et al. 1973, Stephens 1955, Molley unpublished thesis, Sadewasser unpublished thesis, and Van Hoff unpublished thesis). Therefore, it would appear that crayfish use some type of mechanism to measure the duration of the light or dark period.

The mechanism of photoperiodic time measurement may be either an hourglass model or a circadian oscillator model (Pittendrigh 1972). It was the objective of this research to further define the role of photoperiod in the molt cycle of the crayfish *Orconectes immunis* by determining if an hourglass model is a mechanism for photoperiodic time measurement.

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[1] Present address: Department of Zoology, North Carolina State University, Raleigh, NC 27607.

MATERIALS AND METHODS

The crayfish *Orconectes immunis* used in these experiments were obtained from Wolf Lake Fish Hatchery, Kalamazoo County, Michigan, on 2 June and 11 September 1976 and transported immediately to Western Kentucky University. Those animals obtained in June were collected directly from a drained hatchery pond. In September, animals were obtained from the hatchery holding tanks where they had been held at 11 C for approximately 1 week.

The cephalothorax length of the crayfish collected in June ranged from 25.1 mm to 44.5 mm (mean = 35.9 mm) while those obtained in September ranged from 19.2 mm to 37.5 mm (mean = 25.6 mm).

The environmental units used in the experiments provided temperature and light control. Each unit contained 6 separate compartments. The light source in each compartment was a Westinghouse 15-watt coolwhite fluorescent light bulb, wrapped in opaque tape to reduce light to the appropriate intensity. Zinc coated screens with 6-mm mesh were used to cover the crayfish trays, thus allowing penetration of all wavelengths of light. Opaque dividers were placed in the trays since, at least in one instance, lack of privacy in the crab *Gecarcinus lateralis* inhibited molting (Bliss and Boyer 1964). Temperatures in the units were held constant at 22 C.

Two experiments, each containing 2 series were conducted. The first experiment was initiated on 4 June 1976 and the second on 14 September 1976. Experiment 1 was 80 days in duration while Experiment 2 was conducted for 160 days. Series I and II of each experiment were T experiments, in which T was the total length of the light–dark cycle. In Series I, the light phase of the cycle was held at 16 hours with varied lengths of darkness (LD 16;2, T 18: LD 16;8, T 24: LD 16;20, T 36: LD 16;32, T 48). In Series II, the dark phase was 8 hours and the hours of light were varied (LD 2;8, T 10: LD 16;8, T 24: LD 28;8, T 36: LD 40;8, T 48).

In Experiment 1, 2 light intensities were used, 223.56 lux and 413.64 lux. In Experiment 2, intensities of 32.4 lux were used in all treatments.

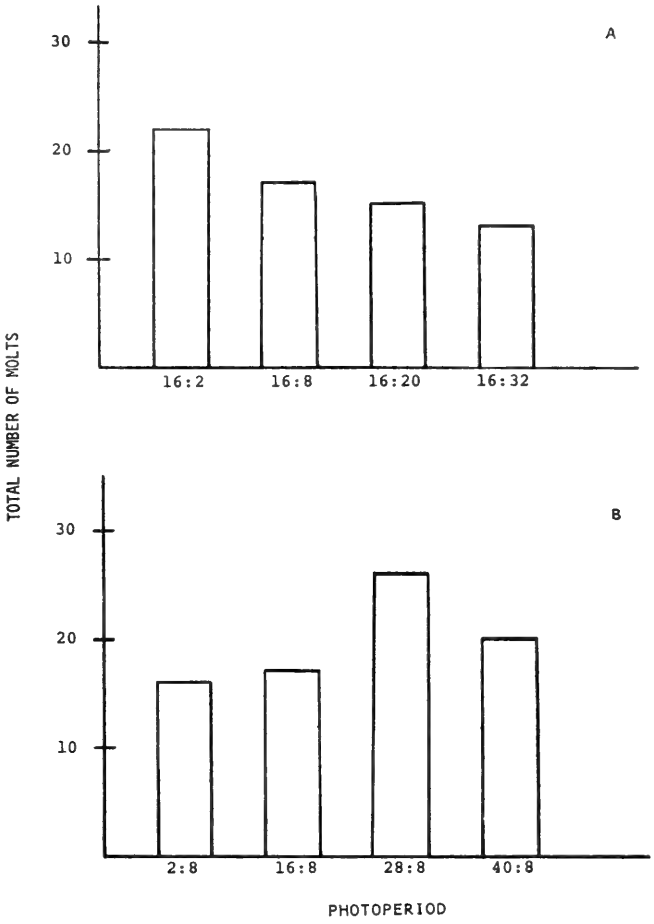

FIG. 1. Total molts occurring in response to 16L: varied dark and varied light:8D photoperiods in Experiment 1 (Series I and II). A. Molts in Series I (16L:Dark). B. Molts in Series II (Light: 8D).

Two hundred and twenty-four crayfish were used in each experiment. In Experiment 1, 7 photoperiod treatments (4 in Series I, and 3 in Series II) were further subdivided into 2 levels of intensity (223.56 lux and 413.64 lux). There was 1 replication of each treatment. Eight animals were assigned to each photoperiod intensity treatment and 8 to each replication. Equal numbers of male and female crayfish were used.

In Experiment 2, there were 7 photoperiod treatments (4 in Series I, and 3 in Series II). There were 3 replications of each treatment. Eight animals were assigned to each photoperiod treatment and

TABLE 1.—ANALYSIS OF VARIANCE OF THE TOTAL MOLTS OCCURRING IN RESPONSE TO PHOTOPERIOD, INTENSITY, AND SEX IN EXPERIMENT 1

Source	Df	SS	MS	F
Total	63	100.48		
Treatment	31	65.98	2.13	1.97[1]
Photoperiod (= A)	7	15.86	2.27	2.10 ns
Intensity (= B)	1	4.52	4.52	4.19[1]
Sex (= C)	1	19.14	19.14	17.75[2]
A × B	7	14.86	2.12	1.97 ns
A × C	7	6.73	0.96	0.89 ns
B × C	1	0.14	0.14	0.13 ns
A × B × C	7	4.73	0.68	0.63 ns
Error	32	34.50	1.08	

[1] Significant at the 0.05 level.
[2] Highly significant at the 0.01 level.
ns = Nonsignificant.

to each replication. Equal numbers of male and female crayfish were used.

The crayfish were checked daily for molts, and shed exoskeletons were left in the trays for the animals to consume. The crayfish trays were rotated at intervals to provide for an even exposure of animals to the light source. The crayfish were given approximately 0.5 g of high protein food every 5 days. Portions of the food not consumed were removed after 4 days.

An analysis of variance (ANOVA) using a completely random design with a factorial arrangement of treatments was used to analyze molting data.

RESULTS AND DISCUSSION

The numbers of molts in each photoperiod in Series I and II of Experiment 1 are presented in Fig. 1. From those data it appeared that the different photoperiods of constant light and varied dark caused similar molting responses in all the crayfish. The analysis of variance (Table 1) confirmed that there were no significant differences in the molting response of the crayfish to the various photoperiods of constant light and varied dark. In Experiment 2, the differences in the molts occurring for each photoperiod of constant dark and varied light were not statistically significant (Fig. 2, Table 2). Therefore, the data indicate that the crayfish were not using an hourglass mechanism for photoperiodic time measurement.

Bowen and Skopik (1976) indicated that the European corn borer *Ostrina nubialis* utilized an hourglass mechanism for measurement of photoperiod. In their experiments the 16L; varied dark conditions caused no termination of diapause except in 16L;8D, indicating that the amount of light or periods of darkness greater than 8 hours were not being measured by an hourglass clock. However, when the 8 hours of darkness were coupled with varying light periods, termination of diapause occurred in every instance. This would indicate that the system of time measurement in *O. nubialis* acted like an hourglass in which photoperiodic time measurement was determined by the length of the dark period. An hourglass model measuring a specific time interval and thereby inducing molts was not used by the crayfish *O. immunis* in those experiments because no constant time interval, when coupled with varying light or darkness, produced an increase in the number of molts.

Significantly greater numbers of molts were obtained in the 413.64 lux light intensity treatments than in the 223.56 lux light intensity treatments in Experiment 1 (Table 1). The reasons for this are not understood. There are few data available on the effects of light intensity on molt responses of crustaceans and the available

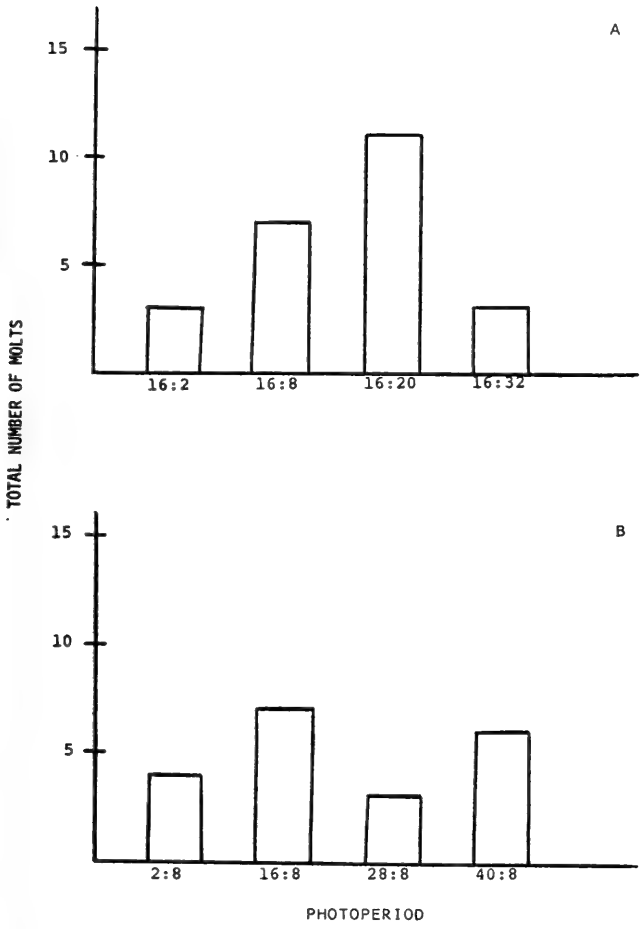

FIG. 2. Total molts occurring in response to 16L: varied dark and varied light:8D photoperiods in Experiment 2 (Series I and II). A. Molts in Series I (16L:Dark). B. Molts in Series II (Light:8D).

data indicate opposite responses from those obtained in these experiments. Prins et al. (1972), when using *O. immunis* from Kentucky, found that molting in the crayfish was less frequent in 120 ft-c (1,296.0 lux) intensities than in 15 ft-c (162.0 lux) intensities when the animals were kept at 22 C. Bliss (1954) found that the molting occurring in the crab *Gecarcinus lateralis* was less when light intensities were greater than 10 lux. Molting responses of crayfish to light intensities are too little understood to draw any conclusions.

In Experiment 1, there were highly significant differences in molting between sexes with females molting more than males (Table 1) (females = 90, males = 37). Tack (1941) suggested that there is an inhibitory mechanism that keeps female *O. immunis*, when bearing young, from molting. The males in our experiment had already started their spring molt when collected, whereas the females had been held from molting until the young were released. This, then, may have caused the differences seen in our experiment.

At this time, it is difficult to determine if seasonal influences such as maturation and development of the gonads affect the crayfish in conjunction with daily photoperiod. It may be that the circadian clocks were setting the patterns of growth and development of the gonads thereby indirectly determining when the crayfish molt. It is not certain if the stage of sexual development affects the measurement of photoperiodic time since no significant interactions between sex and photoperiod were detected.

SUMMARY

1. Experiments were conducted to determine if an hourglass model is a mechanism whereby photoperiodic time is measured by the crayfish *Orconectes immunis*. The effects of photoperiod, intensity, and sex on molting were measured in Experiment 1,

TABLE 2.—ANALYSIS OF VARIANCE OF THE TOTAL MOLTS OCCURRING IN RESPONSE TO PHOTOPERIOD AND SEX IN EXPERIMENT 2. ALL DIFFERENCES (F) WERE NONSIGNIFICANT

Source	Df	SS	MS	F
Total	71	65.99		
Treatment	17	19.24	1.13	1.30
Photoperiod (= A)	8	10.11	1.26	1.46
Sex (= B)	1	1.13	1.13	1.30
A × B	8	8.00	1.00	1.16
Error	54	46.75	0.87	

while the effects of photoperiod and sex were measured in Experiment 2.

2. The crayfish did not use an hourglass model for photoperiodic time measurement under the conditions tested.

3. The crayfish demonstrated significantly greater molts at higher light intensities than at lower light intensities in Experiment 1.

4. In the first experiment, females molted significantly more frequently than males.

LITERATURE CITED

AIKEN, D. E. 1969. Photoperiod, endocrinology, and the crustacean molt cycle. Science 164: 149–155.

ARMITAGE, K. B., A. L. BUIKEMA, JR., AND N. J. WILLEMS. 1973. The effect of photoperiod on organic constituents and molting of the crayfish *Orconectes nais* (Faxon). Comp. Biochem. Physiol. 44A:431–456.

BLISS, D. 1954. Light inhibition or regeneration and growth in the crab *Gecarcinus lateralis*. Anat. Rec. 120:742–743.

———, AND J. R. BOYER. 1964. Environmental regulation of growth in the decapod crustacean *Gecarcinus lateralis*. Gen. Compar. Endocr. 4:15–41.

BOWEN, M. F., AND S. D. SKOPIK. 1976. Insect photoperiodism: The "T Experiment" as evidence for an hourglass mechanism. Science 192:59–60.

HAMNER, K. D. 1960. Circadian rhythms and the time measurement in photoperiodism. Cold Spring Harbor Symp. Quant. Biol. 25: 249–256.

LEES, A. D. 1966. Photoperiodic timing mechanisms in insects. Nature 210:986–989.

MOBBERLY, W. C. 1963. Hormonal and environmental regulation of the molting cycle in the crayfish *Faxonella clypeata*. Tulane Stud. Zool. 11:79–95.

PITTENDRIGH, C. S. 1972. Circadian surfaces and the diversity of possible roles of circadian organization in photoperiodic induction. Proc. Natl. Acad. Sci. 69:2734–2737.

———, AND D. H. MINIS. 1964. The entrainment of circadian oscillations by light and their role as photoperiodic clocks. Amer. Nat. 98:261–294.

PRINS, R., R. RUTEMILLER, AND S. CARDER. 1972. Molting of the crayfish *Orconectes immunis* (Hagen), in relation to temperature, photoperiod, and light intensity. Ass. Southeast. Biol. Bull. 19:93.

RICE, R. R., AND K. B. ARMITAGE. 1974. The influence of photoperiod on processes associated with molting and reproduction in the crayfish *Orconectes nais* (Faxon). Comp. Biochem. Physiol. 47A:234–259.

STEPHENS, G. C. 1955. Induction of molting in the crayfish, *Cambarus*, by modification of daily photoperiod. Biol. Bull. 108:235–241.

TACK, P. I. 1941. The life history and ecology of the crayfish *Cambarus immunis* Hagen. Amer. Midl. Nat. 25:420–446.

WENT, F. W. 1960. Photo- and thermoperiodic effects in plant growth. Cold Spring Harbor Symp. Quant. Biol. 25:221–230.

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Populational Differences in Bud Bursting of *Carpinus caroliniana* Walt.

GORDON I. WARDELL[1] AND JOE E. WINSTEAD
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

Twig samples collected from latitudinally diverse populations (between 31 and 43° N) in winter condition, and subsequently exposed to controlled temperature treatments in growth chambers, indicated ecotypic differences in bud bursting response. Exposure to cold treatment prior to placement under long days (16-hour photoperiod) and warm temperatures (day–night cycle of 24–16 C), reduced time required for bud burst in all populations, but a latitudinal cline was apparent with more southern populations having earlier bud burst. Under longer exposure to cold of at least 4 C, populations from intermediate latitudes showed slower response to bud burst than the extremes of the latitudinal range tested, indicating a protective mechanism to prevent bud burst in more variable habitats with unpredictable spring temperatures.

INTRODUCTION

Since Turesson's (1922) pioneering study of ecotypes, significant research has shown many species to be composed of discrete populations with physiological and morphological differences enabling each population to cope more effectively with its particular environmental regime. Literature reviews have revealed that, when considering the total number of plant species, relatively few have been subjected to intensified or even superficial investigations of populational differentiation (Hiesey and Milner 1965).

Carpinus caroliniana Walt. (commonly called ironwood, blue beech, American hornbeam, or water beech; Fernald 1950) is a dominant understory species in eastern North America; its range extends from Nova Scotia to Minnesota and south to Texas and Florida. Wide distribution and relative abundance makes ironwood an ideal species for ecotypic and community investigations.

Despite the abundance of *Carpinus caroliniana*, very little information has been published about it. A survey of such references as EXCERPTA BOTANICA, BIOLOGICAL ABSTRACTS, and DISSERTATION ABSTRACTS confirmed that there is virtually no information on the autecology of the genus. This is not unexpected since it is currently of little economic importance. As wood and fiber demands increase, this seemingly noneconomic tree may prove to be an important source of wood fiber. In the past, ironwood has been utilized for wagon axles, spokes, implement handles, and mallet heads, and charcoal of hornbeam was often mixed with gunpowder (deWit 1966). *Carpinus* reportedly accumulates higher than normal amounts of aluminum (Kruckeburg 1969) availing it as a subject for investigating the possibility of its functional niche as an aluminum pump. Populational variation in fruit size has been reported, with larger fruit being evident from more northern habitats (Winstead et al. 1977). The current study is an investigation of the aspects of populational variation in terms of bud bursting.

[1] Permanent mailing address: 6810 Bordman Rd., Almont, Michigan 48003.

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TABLE 1.—LOCATION AND DESCRIPTION OF 9 COLLECTION SITES OF *Carpinus caroliniana* FROM MICHIGAN TO ALABAMA. ALL POPULATIONS WERE BETWEEN 83°12′ AND 86°49′ W LONGITUDE

Population Code	County	State	N. Lat.
M1	Isabella	Michigan	43°29′
M2	Lapeer	Michigan	42°58′
I1	Scott	Indiana	38°42′
K1	Grayson	Kentucky	37°33′
K2	Simpson	Kentucky	36°43′
T1	Davidson	Tennessee	36°07′
A1	Limestone	Alabama	34°48′
A2	Montgomery	Alabama	32°18′
A3	Covington	Alabama	31°10′

MATERIALS AND METHODS

Collection sites were established for comparisons of widespread populations along a north–south line between 83 and 86°W and a latitudinal distribution between 31 and 43°N (Table 1).

Buds were collected in late December 1975 from 2 trees at each of 9 sites (Table 1), placed in a cold chamber, and maintained at 4 C until removed for testing. Twenty twigs from each population were cut to approximately 20 cm, put in a test tube with tap water, and covered with a plastic bag. The twigs were then placed in an environmental growth chamber (Environator Corporation model 3448) with a day–night temperature of 24–16 C and a 16-hour photoperiod with light intensities of 6,500 to 8,600 lux. All buds were checked daily for evidence of bursting.

Periods of exposure to temperatures below 4 C in the field were calculated for each population from information provided by the National Climatic Center, National Oceanic and Atmospheric Administration, Asheville, N.C.

RESULTS

Winter buds of *Carpinus* collected from field populations and placed in a growth

TABLE 2.—POPULATIONAL DIFFERENCES IN BUD BURSTING OF *Carpinus caroliniana* UNDER CONTROLLED ENVIRONMENTAL CONDITIONS OF 16-HOUR DAYS AND 24–16 C

Population Code	M1	M2	I2	K1	K2	T1	A1	A2	A3
PROGRAM I									
Days below 4 C prior to test[1]	75	80	72	61	43	51	56	40	47
Days required for 25% bud burst	33	—	34	19	26	23	20	18	18
Days required for 50% bud burst	—	—	51	20	27	27	22	18	19
PROGRAM II									
Days below 4 C prior to test	97	102	93	83	65	72	78	62	69
Days required for 25% bud burst	18	19	26	16	17	17	14	12	13
Days required for 50% bud burst	21	23	28	18	20	19	14	13	13
PROGRAM III									
Days below 4 C prior to test	118	123	114	104	86	93	99	83	90
Days required for 25% bud burst	9	11	19	10	10	9	9	9	8
Days required for 50% bud burst	10	14	—	13	12	13	10	10	9

[1] Days below 4 C prior to test include field conditions before 9 Jan 1976, as well as days held in cold chamber at 4 C subsequent to collection. Program II conditions include an additional 22 days of 4 C than twig cuttings in Program I; Program III conditions include an additional 21 days of 4 C than Program II and 43 days additional cold treatment than Program I.

chamber at regular intervals displayed a possible ecotypic response to the amount of cold experienced prior to springlike conditions. After a minimum of 40 to 80 days at 4 C, a latitudinal response in bud bursting could be seen from Michigan to Alabama (Program I, Table 2). The southernmost populations exhibited 50 percent bud initiation after only 19 days in the growth chamber. As latitude increased northward, so did the time required for maximum bud bursting (up to 51 days).

When subjected to a minimum of 62 to 102 days at 4 C, the time required for 50 percent bud bursting decreased for all latitudes (Program II, Table 1). The Alabama populations continued to display the earliest bud bursting, while the central and northern populations required longer periods to attain 50 percent bud bursting.

The third set of buds (Program III) placed in the growth chamber for 83 to 123 days below 4 C, showed that the northern and southern populations experienced bud bursting at approximately the same time. The material from the central latitudes required a considerably longer period of warm temperatures before initiating spring activity.

DISCUSSION

Winter buds collected from latitudinally diverse field populations demonstrated a high degree of interpopulational variation in response to cold temperature preconditioning. After receiving only 40 to 80 days of temperatures below 4 C, the first program showed apparent latitudinal response to bud bursting with a longer time period required as latitude increased. McMillian and Peacock (1964) documented a similar response in *Prosopis* (mesquite) grown under uniform conditions. They concluded that late bud bursting in northern populations (Oklahoma and Texas) was a selective advantage, preventing frost damage after early warm periods.

The second program of 62 to 102 minimum days at 4 C depicted a similar pattern but with a shorter time between maximum bud bursting in the north and south. Following 83 to 123 days at 4 C, the third program revealed the central latitude populations (Indiana, Kentucky, and Tennessee) retaining the longest dormancy. The northern and southern populations experienced bud bursting at approximately the same time. McNaughton (1967) reported a similar response in altitudinally diverse forest community samples placed under controlled environmental conditions. He reported that woody plants originating from the intermediate elevations required a greater time for maximum bud bursting that did either of the extreme elevations. McNaughton proposed that unstable temperature and frequent late frosts of the intermediate altitudes selected against the early bud bursting genotypes. In regard to *Carpinus*, the central latitudes are noted for their winter thaws and warm periods followed by frost. Without a protective mechanism to prevent spring bud initiation, frost damage would be severe. On the other hand, when spring begins in the northern and southern extremes there is generally little variation, and no need for an extended dormancy.

It may be concluded from this study that ironwood bud bursting is primarily dependent on 2 factors: (1) the amount of cold preconditioning experienced prior to springlike conditions, and (2) the duration of cold necessary to break winter dormancy varies with latitude. Extended cold requirements of the populations at central latitudes in the eastern United States can be viewed as a protective mechanism that impedes spring development during brief warm periods in the winter.

LITERATURE CITED

deWIT, H. C. D. 1966. Plants of the World. E. P. Dutton and Co., Inc., New York, N.Y. 208 pp.

FERNALD, M. L. 1950. Gray's Manual of Botany. American Book Co., New York, N.Y. 1632 pp.

HIESEY, W. M., AND H. W. MILNER. 1965.

Physiological and ecological races and species. Ann. Rev. Plant Physiol. 16:203–216.

KRUCKEBURG, A. R. 1969. Soil diversity and the distribution of plants with examples from North America. Madroño 20(3):129–154.

MCMILLIAN, C., AND J. T. PEACOCK. 1964. Bud bursting in diverse populations of mesquite (*Prosopis*: Leguminosae) under uniform conditions. Southwest. Nat. 9(3):181–188.

MCNAUGHTON, S. J. 1967. Genetic control of bud bursting in altitudinally diverse Cascade Forest community samples. Amer. Midl. Nat. 77(2):528–532.

TURRESON, G. 1922. The genotypical response of the plant species to the habitat. Hereditas 3:211–350.

WINSTEAD, J. E., B. J. SMITH, AND G. I. WARDELL. 1977. Fruit weight clines in populations of ash, ironwood, cherry, dogwood and maple. Castanea 42:56–60.

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Age and Growth, Length-Weight Relationships, and Condition Factors of the Greenside Darter from Silver Creek, Kentucky

G. William Wolfe[1], Bruce H. Bauer[1], and Branley A. Branson
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Data on age and growth were obtained from 203 greenside darters from Silver Creek, Madison County, Kentucky, during February and March 1973. The fish length–scale length relationship was TL = 20.16 + 0.9937 SR. Males were larger than females at all ages, but relative to their respective calculated maximum lengths, females grew more rapidly except during the last year of life. The length–weight relationship was log W = −5.1894 + 3.1199 log L for the combined sexes. Condition factor (K) increased with age, but there was no significant difference between males and females.

Introduction

The greenside darter is a common inhabitant of streams of the Great Lakes, and Mississippi and Potomac river drainages. In Kentucky, the adults are typically found over bedrock in swift, deep riffles, while the juveniles may be found in less violent habitats. It is the largest member of the subgenus *Etheostoma* and characteristically has a complete lateral line, gill membranes broadly connected, frenum well developed, large, expansive pectoral fins, and sides with about 8 double bars, each pair forming a U-shaped figure.

No data on age and growth of the greenside darter are available for Kentucky, and few such data are available for the species from other states. Growth information is often necessary for studies of maturity, mortality rates, and population dynamics. This study provides information on growth, length–weight relationships, age structure, condition factors, and sex ratios of *E. blennioides* in a Kentucky stream. Regional comparisons were made with growth studies on *E. blennioides* in Pennsylvania (Lachner et al. 1950) and New York (Fahy 1954).

Materials and Methods

Two hundred three greenside darters were taken in 5 collections at 3 different stations in Silver Creek, a tributary to the Kentucky River, Madison County, Kentucky, during February and March 1973. All fish were preserved in 10 percent formalin, numbered, measured to the nearest millimeter (total length), weighed to the nearest 0.1 g, and sexed.

Approximately 10 scales were removed from the right side of each darter, below the lateral line, and at the tip of the compressed pectoral fin. At least 4 scales were cleaned with a bleach solution, mounted between glass slides, and examined with a microprojector (80× magnification). The distance from the focus to the anterior margin of the scale and to each annulus was measured to the nearest millimeter along the radius most nearly colinear with the focus, as described by Hile (1954). The identification number of the fish from which the scales were taken was recorded on each slide. All scales were prepared at the same time and read without immediate knowledge of the fish from which they came to prevent bias in age determination because of the size of the fish (Marcy 1969).

[1] Present address: Department of Zoology, University of Tennessee, Knoxville, Tennessee 37916.

The body–scale relationship was: TL = 20.16 + 0.9937 SR, where TL = total length and SR = anterior scale radius (at 80×). The body scale relationship was linear (r = 0.989) and required no transformations.

Time of annulus formation could not be determined, although gonadal development indicated that the time of capture was very close to the advent of spawning and, therefore, all fish were assumed to have completed at least 1 year of life. An annulus was distinguished from an accessory mark as a zone of closely spaced circuli followed by a zone of widely spaced circuli and by the cutting over of circuli in the lateral fields.

Calculations of length at each annulus were made from measurements of the anterior radius applied in the formula $L_i = c + (S_i/S)\ (L\text{-}C)$, where L_i is the length of the fish at time of annulus formation, C is the length of the fish at time of back-calculated scale formation (20.16 mm), S_i is the length of the anterior radius of the scale at each annulus, S is the length of the anterior radius at capture, and L is the total length of the fish at capture.

Coefficients of condition (K) were calculated using the formula $K = W/L^3 \times 10^4$, where W = weight in grams and L = total length in millimeters. The length–weight relationships were computed following the method of Jester and Jensen (1972).

Results and Discussion

The mean calculated total lengths of Silver Creek *E. blennioides* in Age Groups I through V were 60.0, 73.2, 84.8, 85.0, and 83.5 mm, respectively (Table 1). Males attained greater lengths than females at all ages. The mean calculated total lengths of males through 4 age groups were 61.6, 74.1, 87.4, and 95.5 mm, and for females through 5 age groups were 58.7, 72.1, 80.8, 81.5, and 83.5 mm. Fahy (1954), in New York, and Lachner et al. (1950), in Pennsylvania, found similar results, but typically *E. blennioides* from Silver Creek were longer than those from either Pennsylvania or New York.

Back calculations of length frequently exhibit a tendency for computed lengths at a given age to be smaller, the older the fish from which they were computed (Tesch 1971). This is commonly known as "Rosa Lee's phenomenon." The data in Table 1 represent a reversal of this which might possibly have been due to a size selective mortality that acted more severely on the smaller fish of an age group.

In Silver Creek, *E. blennioides* males attained 64.5 percent of their calculated maximum mean length during their first year and 77.6 percent by the second year. Females grew faster relative to their own calculated maximum length, attaining 70.3 and 86.3 percent during their first and second years, respectively. Lachner et al. (1950), found that after 2 years, males attained 76.3 percent of their maximum lengths, and females 90.2 percent. Fahy (1954) found male and female growth to be 84 and 82 percent, respectively, after 2 years of life.

The more rapid rate of growth of females was not manifested in the last year of life in either Kentucky or Pennsylvania. The present study indicates that during their last year of life, males grew 7.2 mm (7.5% of maximum growth) and females grew 4.0 mm (4.8%). In Pennsylvania, males grew 8.1 mm (10.5%) and females 0.5 mm (0.8%) during their last year. Fahy (1954) found that in New York males and females had more equal growth, with the males growing 3.8 mm (5.2%) and females 3.7 mm (5.2%) during their last year.

Few fish survived to Age Group IV. Although there were more females than males in Age Group I, more males than females survived to Age Group III. A Chi-Square analysis of the sex ratios revealed that the females significantly outnumbered the males in age group I ($P = 0.01$). In Age Group II, no significant difference was noted, however, by Age Group III there were significantly more males than females ($P = 0.05$). Although females outnumbered

TABLE 1.—MEAN CALCULATED TOTAL LENGTHS OF 203 *E. blennioides*. THE DATA IS SHOWN FOR MALES, FEMALES, AND BOTH SEXES

Age Group	Sex	No. of Fish	Mean calculated total lengths at each annulus				
			1	2	3	4	5
I	Males	40	61.3				
	Females	67	56.9				
	Both	107	58.6				
II	Males	31	58.8	69.8			
	Females	27	61.6	71.2			
	Both	58	60.1	70.4			
III	Males	21	65.6	79.6	87.3		
	Females	9	63.0	75.7	83.1		
	Both	30	64.8	78.4	86.0		
IV	Males	2	68.8	82.6	88.3	95.5	
	Females	4	60.6	72.9	78.7	82.5	
	Both	6	66.3	76.1	81.9	86.8	
V	Males	—	—	—	—	—	—
	Females	2	54.5	66.5	75.0	79.5	83.5
	Both	2	54.5	66.5	75.0	79.5	83.5
Mean Total Lengths	Males	94	61.6	74.1	87.4	95.5	
	Females	109	58.7	72.1	80.8	81.5	83.5
	Both	203	60.0	73.2	84.8	85.0	83.5

males in Age Group IV (4:2), the sample size of 6 fish may not be representative. Only 2 fish were captured from Age Group V, both were females.

Equations for length–weight relationships were calculated after lengths and weights were transformed into logs (base 10). The length–weight equation for males (n = 94) was: Log W = 5.4007 + 3.2278 log L (r = .998) and for the females (n = 109) was: log W = 4.9038 + 2.9713 log L (r = .993). The slope of the length–weight relationship of the males was 3.2278 indicating that the relative weight of the fish increased faster than the length (Ricker 1971). The females have a slope of 2.9713 indicating a slightly faster increase in length when compared to weight. An analysis of covariance (Sokal and Rohlf 1969) indicated that there was no significant difference between the slopes at the 0.05 level; therefore the length–weight relationship for all fish (n = 203) regardless of sex was: log W = 5.1894 + 3.1199 log L (r = .995) (Fig. 1).

Condition factors for *E. blennioides* (Table 2) show an increase with increasing

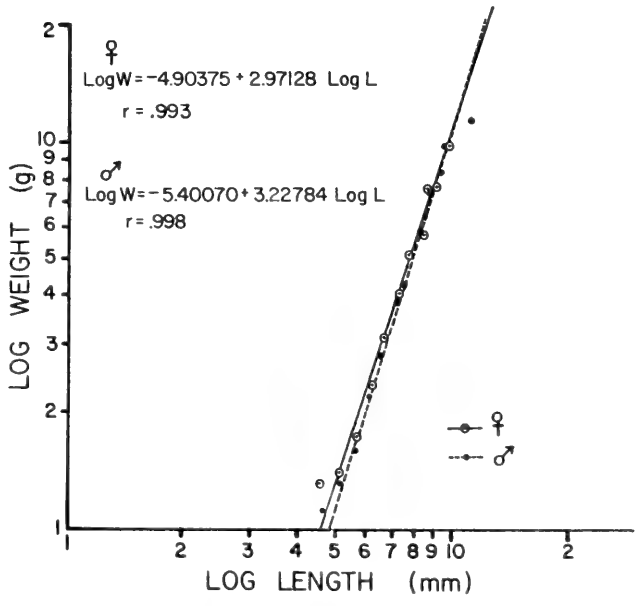

FIG. 1. Length-weight relationship of *Etheostoma blennioides* plotted on log-log paper.

TABLE 2.—COMPARISON OF MALE AND FEMALE *E. blennioides* CONDITION FACTORS FOR EACH AGE GROUP

Age group	Males		Females		Total	
	No.	K	No.	K	No.	K
I	40	1.0071	67	1.0423	107	1.0292
II	31	1.0436	27	1.0846	58	1.0627
III	21	1.1426	9	1.1484	30	1.1443
IV	2	1.1505	4	1.1731	6	1.1655
V	—	—	2	1.1605	2	1.1605

age in both sexes. Although female condition factors were greater at all ages, none of the differences were significant when analyzed by means of a nonparametric *t*-test. The slightly greater values for the females probably was due to their increased weight resulting from ovarian development prior to spawning.

SUMMARY

Age and growth of 203 *Etheostoma blennioides* from Silver Creek, Madison County, Kentucky, indicate that males grew larger than females, but, females grew faster relative to their own maximum lengths. Similar studies on *E. blennioides* in New York and Pennsylvania also demonstrated that males were larger than females. Kentucky specimens were larger than either those of New York or Pennsylvania. The slope of the male length–weight relationship was slightly but not significantly greater than that of the females. Although females significantly outnumbered males in Age Group I, by Age Group III, males significantly outnumbered females. Female condition factors were slightly, but not significantly, greater than those of males.

LITERATURE CITED

FAHY, W. R. 1954. The life history of the northern greensided darter *Etheostoma blennioides blennioides* Rafinesque. J. Elisha Mitchell Sci. Soc. 70(2):139–205.

HILE, R. 1954. Fluctuations in growth and year-class strength of the walleye in Saginaw Bay. U.S. Fish Wildl. Serv., Fish. Bull. 56: 7–59.

JESTER, D. B., AND B. L. JENSEN. 1972. Life history and ecology of the gizzard shad, *Dorosoma cepedianum* (Le Sueur) with reference to Elephant Butte Lake. N. Mex. St. Univ. Agric. Exp. Sta. Res. Rept. 218:1–55.

LACHNER, E. A., E. F. WESTLAKE, AND P. S. HANDWERK. 1950. Studies on the biology of some percid fishes from western Pennsylvania. Amer. Midl. Nat. 43(1):92–111.

MARCY, B. C. 1969. Age determination from scales of *Alosa pseudoharengus* (Wilson) and *Alosa aestivalis* (Mitchill) in Connecticut waters. Trans. Amer. Fish. Soc. 98(4):622–630.

RICKER, W. E. 1971. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Sci. Publ. Oxford and Edinburgh, Eng. 313 pp.

SOKAL, R. R., AND F. J. ROHLF. 1969. Biometry. W. H. Freeman & Co., San Francisco, Cal. 776 pp.

TESCH, F. W. 1971. Age and Growth. Pp. 93–123. *In*: Methods of assessment of fish production in fresh waters. W. E. Ricker (Ed.). IBP Handbook No. 3. Blackwell Sci. Publ., Oxford and Edinburgh, Eng. 313 pp.

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The Ecological Status of Six Rare Plants in Kentucky, with Reference to a Recent Publication on Endangered Species

Jerry M. Baskin and Carol C. Baskin
School of Biological Sciences, University of Kentucky, Lexington, Kentucky 40506

Abstract

Documented comments on the occurrence of 6 rare plant species in Kentucky include 5 species referred to in a recent publication entitled "Endangered Plants and Animals of Kentucky" by Jan V. Babcock. Evidence is presented to show that the actual ecological status of 5 of those species in Kentucky is quite different from that reported by Babcock, and the sixth species, *Satureja glabella*, was not mentioned. The scientific merit of the plant section of Babcock's publication is questioned.

Introduction

Jan V. Babcock (1977) recently compiled a book entitled "Endangered Plants and Animals of Kentucky." With regard to the plant species in that publication, there are gross inaccuracies concerning their present ecological status in Kentucky, and some rare species that occur in Kentucky were not included. The purpose of this article is to comment on the ecological status of 6 of the Commonwealth's rare plant species, with special reference to Babcock's book. Those 6 species not only are rare in Kentucky but are rare throughout their narrow geographic ranges.

Viola egglestonii Brainerd

Babcock indicated that *V. egglestonii* occurs in Warren, Hart, and Bullitt counties and suggested, by symbols on his map, that the species is "abundant" in Warren County and "common" in Hart and Bullitt counties. The only mention in the literature of *V. egglestonii* in Warren County is in a report entitled "Violets of North America" by Ezra Brainerd in 1921. In that report, Brainerd mentioned a single specimen collected by Sadie F. Price from near Bowling Green in Warren County on 11 April 1899. The only report of its occurrence in Hart County was by Braun (1943) who had a single collection of it from Hart County. Furthermore, Braun did not list *V. egglestonii* as occurring in Warren County, and Hart is the only county from which she had a collection of it. We (Baskin and Baskin 1978) have searched the cedar glades, the natural habitat of *V. egglestonii*, in Warren and Hart counties and have not found it in either county. Furthermore, in a taxonomic treatment of the violets of central and eastern United States, Russell (1965) did not indicate that *V. egglestonii* occurred in Kentucky because he could not find herbarium specimens to document its occurrence there.

We recently discovered a few small populations of *V. egglestonii* on Silurian limestone in eastern Bullitt County (Baskin and Baskin 1975), but the species certainly is not common there, contrary to what is indicated on Babcock's distribution map. In 1975, Bullitt was the only county in Kentucky in which living populations of *V. egglestonii* were known to occur. More recently, however, we found 3 small populations in Nelson County, south of Bardstown (Baskin and Baskin 1978).

Leavenworthia torulosa Gray

Babcock depicted *L. torulosa* as "abundant" in Warren County, "common" in Logan County, and "probable" in Simpson County. For Warren County, he gave 1 specific location, "twelve miles north of U.S. 68," which he must have taken from Rollins (1963). In his field studies of the

genus *Leavenworthia*, Rollins (1963) found only 1 population of *L. torulosa* in Kentucky and gave its location as "cedar glade situation, 12 mi. north of U.S. Highway 68 on state route 1083, Warren County." Nowhere in his book did Babcock refer to Rollin's monograph.

Presently, only 2 extremely small populations, 1 in Warren County and 1 in Logan County, are known in Kentucky, and the Warren County population referred to by Rollins no longer exists (Baskin and Baskin 1977). Certainly, *L. torulosa* is not common or abundant anywhere in Kentucky, and probably never was. The reasons we conclude it never was common or abundant are: (1) its specialized cedar glade habitat of seasonally wet or flooded shallow soil over limestone in pools or depressions is not common, and (2) very few collections of the species have ever been made in Kentucky. The species was collected by Short in 1840, Rollins and Channell in 1959 (Rollins 1963), and Baskin and Baskin in 1973 (Baskin and Baskin 1977). Rollins made the following statement concerning the occurrence of *L. torulosa* in Kentucky "I searched for the species in Kentucky in three different years before finding it and I have not seen any specimens from that state collected in the interim between those of Short in the 1840's and the small population we found in 1959."

Leavenworthia exigua var. *laciniata* Rollins

Babcock wrote that *L. exigua* var. *laciniata* is "common" in Bullitt and Jefferson counties. As with other plant species in his book, Babcock did not cite specific literature references or herbarium specimens. Rollins (1963), who first described that variety of *L. exigua*, gave only 1 location, on Ridge Road in Bullitt County, Kentucky, and he cited only 2 collections from that site. *Leavenworthia exigua* var. *laciniata* does occur in Bullitt and Jefferson counties, as Babcock indicated, but it is not common. We have searched extensively for *L. exigua* var. *laciniata* in Bullitt County and in the southern portion of Jefferson County. It is fairly common in a small portion of eastern Bullitt County, but we have found only 1 small population in Jefferson County, just north of the Bullitt–Jefferson County line.

Conradina verticillata Jennison

Babcock noted that *C. verticillata* is "common" in McCreary County, but then described its distribution in Kentucky as "South Fork of Cumberland River, submerged upon completion of Wolfe Creek Dam." Braun (1936) first reported the species from Kentucky along the banks of the South Fork of the Cumberland River in McCreary County. Apparently, that is the only locality from which the plant has ever been collected in Kentucky. In his synopsis of *Conradina*, Shinners (1962) cited specimens from a single collection of *C. verticillata* made by Braun at the above locality on 18 June 1935. Gray (1965, unpublished doctoral dissertation, Vanderbilt University, Nashville, Tennessee) in his study of *Conradina*, cited specimens collected by Braun at the same locality on 6 September 1934 and 18 June 1935. In her catalogue of Kentucky spermatophytes, Braun (1943) wrote "Very rare and local on banks of South Fork Cumberland River, where it will be submerged upon completion of the Wolf Creek dam: *McCreary*."

Gray (unpublished dissertation) doubted that *C. verticillata* still exists in McCreary County, Kentucky, and wrote ". . . the only reported station of its occurrence (Braun 1936) is situated upstream from the present site of Wolf Creek Dam on the South Fork of the Cumberland River. The presumed site of the population is now submerged."

Apios priceana Robinson

Babcock noted *A. priceana* as occurring only in Warren County and suggested that its occurrence is only "probable." According to Browne and Athey (1976), specimens collected by Sadie F. Price near Bowling Green in Warren County are on deposit in GH, NY, and US. Those specimens probably were collected in the late 1890s. The species has been collected

in at least 3 other Kentucky counties in the 1970s. In their study of the flora of the Land Between the Lakes of Kentucky and Tennessee, Ellis et al. (1971) reported the species from Trigg County, Kentucky. More recently, Browne and Athey (1976) reported it from Livingston and Lyon counties, Kentucky.

Satureja glabella (Michx.) Briq.

Satureja glabella is an example of a rare plant in Kentucky (and throughout its range) that was not included in Babcock's treatment. The species is known only from a few localities in middle Tennessee, northwestern Arkansas, and central Kentucky (Baskin and Baskin unpublished information). The University of Kentucky herbarium has 2 specimens of *S. glabella* [labeled *Cunila glabella* Michx., an old synonym for *Satureja glabella* (Michx.) Briq.] collected by Short. One specimen was collected in 1836 but has no collection site, and the other specimen has neither a date nor a collection site. In 1943, Braun said that the species occurred in Henry and Owen counties. Since then, Wharton (No. 10,267b in UK, 9 August 1956) has collected *S. glabella* in Franklin County, making a total of 3 Kentucky counties from which the species has been collected.

CONCLUSION

We conclude that the plant section of Babcock's book contains inaccuracies and should be used with caution as a source of floral documentation in preparation of environmental assessments by federal or state agencies or contractual consultants to those agencies.

LITERATURE CITED

BABCOCK, J. V. 1977. Endangered plants and animals in Kentucky. A publication of the Office of Research and Engineering Services. Coll. Engin., Univ. Ky. Lexington, Ky. 128 pp.

BASKIN, J. M., AND C. C. BASKIN. 1975. Geographical distribution of the cedar glade endemic *Viola egglestonii*. Rhodora 77:427–429.

————, AND ————. 1977. *Leavenworthia torulosa* Gray: An endangered plant species in Kentucky. Castanea 42:15–17.

————, AND ————. 1978. On the occurrence of the cedar glade endemic *Viola egglestonii* in Kentucky. Trans. Ky. Acad. Sci. 39(1–2):74–75.

BRAINERD, E. 1921. Violets of North America. Vt. Agric. Exp. Sta. Bull. 224: 172 pp.

BRAUN, E. L. 1936. Notes on Kentucky plants I. Castanea 1:41–45.

————. 1943. An annotated catalogue of the spermatophytes of Kentucky. Cincinnati, Ohio. 161 pp.

BROWNE, E. T., JR., AND R. ATHEY. 1976. Herbarium and field studies of Kentucky plants. III. New or rare flowering plants in western Kentucky. J. Elisha Mitchell Sci. Soc. 92: 104–109.

ELLIS, W., E. WOFFORD, AND E. CHESTER. 1971. A preliminary checklist of the flowering plants of the Land Between the Lakes. Castanea 36:229–246.

ROLLINS, R. C. 1963. The evolution and systematics of *Leavenworthia* (Cruciferae). Contrib. Gray Herbarium Harvard Univ. No. 192: 3–98.

RUSSELL, N. H. 1965. Violets (*Viola*) of central and eastern United States. Sida 2:1–113.

SHINNERS, L. H. 1962. Synopsis of *Conradina* (Labiatae). Sida 1:84–88.

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Kentucky's High Country—A Biological Treasure

Wayne H. Davis and Roger W. Barbour
School of Biological Sciences,
University of Kentucky, Lexington, Kentucky 40506

Abstract

Big Black Mountain and other peaks and ridges in the counties bordering Virginia in southeastern Kentucky harbor a variety of northern species of plants, insects, birds, and mammals found nowhere else in the state. The isolation of those peaks from the main range of the Appalachians and Smokies makes them especially interesting to students of evolution. Except for the ridge within Cumberland Gap National Historical Park, all of Kentucky's high country is threatened by the destructive effects of strip mining for coal.

Introduction

Many northern species of plants and animals range southward along the Appalachian chain into the Great Smokies. Kentucky, lying to the west of those high peaks and ridges, is outside the range of many of them. Big Black Mountain, elevation 4,150 feet (1,277 m), the highest point in Kentucky, does support a population of several of those northern species.

Our northern species probably arrived there in front of the Pleistocene ice cap that at one time extended southward to what is now Cincinnati, Ohio. During that time, many northern species of plants and animals probably were abundant and widespread there; the fossil record shows several modern species of northern mammals in central Kentucky (Guilday et al. 1971). Now, of course, with the consistently warmer weather over the past hundred or so centuries, the only ones that have persisted are those that inhabited the mountains, or found sanctuary in cool deep coves and gorges.

Big Black Mountain

The best known, and most intensively studied of our higher mountains is Big Black Mountain, in Harlan County (Kellogg 1939; Braun 1940, 1941a, 1941b, 1942; Barbour 1941, 1950a, 1950b, 1950c, 1951, 1952, 1953; Barbour and Smith 1956; Breiding 1947; Lovell 1950; Mengel 1965; Croft 1969). Surely, it harbors a wider array of northern species than any other mountain in Kentucky. We are personally familiar with 23 species of plants and animals whose distribution in Kentucky is essentially limited to that mountain. Only a few of them are known to breed elsewhere in the state, and then in only a few localities.

Wildflowers:

Turk's-cap lily	*Lilium superbum* L.
Canada mayflower	*Maianthemum canadense* Desf.
Painted trillium	*Trillium undulatum* Willd.

Trees and Shrubs:

Yellow birch	*Betula lutea* Michx.
Mountain magnolia	*Magnolia fraseri* Walt.
Mountain winterberry	*Ilex montana* T. & G.
Striped maple	*Acer pensylvanicum* L.
Red-berried elder	*Sambucus racemosa* Fern.
Red azalea	*Rhododendron bakeri* Lemmon

Birds:

Veery	*Hylocichla fuscescens*
Solitary vireo	*Vireo solitarius*
Golden-winged warbler	*Vermivora chrysoptera*
Black-throated blue warbler	*Dendroica caerulescens*
Blackburnian warbler	*Dendroica fusca*
Chestnut-sided warbler	*Dendroica pensylvanica*
Canada warbler	*Wilsonia canadensis*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Slate-colored junco	*Junco hyemalis*

Mammals:

Masked shrew	*Sorex cinereus*
New England cottontail	*Sylvilagus transitionalis*
Deermouse	*Peromyscus maniculatus*
Red-backed mouse	*Clethrionomys gapperi*
Woodland jumping mouse	*Napaeozapus insignis*

Dr. E. Lucy Braun (1941, 1942) listed 3 additional plant species from Big Black Mountain with which we are unfamiliar: *Carex aestivalis* M. A. Curtis, *C. leptonervia* Fern., and *Solidago curtisii* T. & G.

Dr. Thomas C. Barr, Jr., who has been studying relict species of carabid beetles in the Appalachians, has given us the following list of interesting beetles he has found on top of Big Black Mountain, most of which are known in Kentucky only from that locality.

Cychrines (snail-eaters):

Scaphinotus webbi. Perhaps a new subspecies.
Scaphinotus andrewsi germari
Sphaeroderus canadensis

Annilines (minute, eyeless soil beetles):

Annillinus sp. undescribed. Nearest relative is found in a cave in Alabama.

Trechines:

Trechus hydropicus canus. Until now, thought to be endemic to southwestern Virginia.

Anchomenines:

Platynus gracilentus. A glacial relict species that forms hybrid swarms with *P. angustatus* and thus is of special evolutionary interest.

Carabines:

Carabus limbatus

Pterostichines:

Pterostichus rostratus
Pterostichus lachrymosus

Dr. Barr believes that fieldwork would most likely reveal several additional species of interesting beetles in the Kentucky High Country.

That Kentucky's relict populations of northern species have long been isolated is evident from an examination of our red-backed mice. They constitute a well-marked subspecies *C. g. maurus* (Kellogg 1939) that has been reported only from Big Black Mountain and nearby Big Stone Gap, Virginia. They are much darker than red-backed mice from any other region.

Our northern birds, with their greater mobility, are not as isolated from other mountaintop populations, and all the species one would expect on a 4,000-foot (1,219-m) mountain at this latitude are found on Big Black Mountain.

Other Ridges and Peaks

There are other ridges and peaks in Kentucky high enough to support northern species of birds and mammals. Cumberland Mountain in Cumberland Gap National Historical Park, rises to 3,513 feet (1,081 m). The Park contains several north-facing slopes, ravines, streams, and meadows above 3,000 feet (914 m). Log Mountain, rising to about 3,200 feet (985 m) behind Chenoa in western Bell County, is the westernmost mountain habitat in Kentucky, some 90 km from Big Black Mountain. About midway between those localities, in the vicinity of Alva, are numerous peaks, ridges, and spurs ranging in elevation from 2,900 to 3,400 feet (892–1,046 m). Except for a trail along one ridge and a fire tower on one peak, the mountaintops around Alva seem to be nearly inaccessible. Probably, some support northern species.

Pine Mountain, a single straight ridge running nearly the length of southeastern Kentucky, rises in some places to about 2,800 feet (862 m). However, the north-facing slope is extremely steep, nearly clifflike, and the ridge is rather arid, making the mountain a rather poor prospect for northern species, but some may well be there. A spur from Pine Mountain, between Hellier and Dorton in Pike County, contains an extensive flat area at 2,600 feet (800 m) and a peak rising above 2,800 feet (862 m). This area, known as

Flatwoods, apparently has not been investigated.

Croft (1969) studied the breeding birds of Cumberland Mountain that is accessible by hiking trails through the National Park. He found several species of northern birds but no juncos, rose-breasted grosbeaks, or blackburnian warblers. Perhaps Big Black Mountain is the only place in Kentucky high enough to support those species. Croft also visited Log Mountain and reported it to be accessible via strip mine roads.

We are presently surveying the vertebrate fauna of Cumberland Gap National Historical Park, and have captured red-backed mice and deermice on Cumberland Mountain, providing a second locality for those interesting mammals in Kentucky.

Unfortunately, all of Kentucky's high country is underlain with large quantities of high quality coal in several seams at different elevations. Contour and auger mining is proceeding at such a rapidly accelerating rate that the industry reports that surface mining will be essentially completed in the Eastern Kentucky Coalfields within 12 years. We fear that contour benches and auger holes will affect the hydrology of the mountaintops, draining the moisture necessary to support most northern species. Only the National Park seems safe from assult by the strip miners.

Efforts should be made to preserve more of Kentucky's northern treasure before it is lost forever. Big Black Mountain must be saved. To the naturalist, it is the single most interesting locality in the state, *the* place to go to find northern birds, mammals, and plants. Already heavily scarred by strip mining, Big Black Mountain is the most important conservation problem in the state.

An effort should be made to survey the flora and fauna of the several dozen or so mountain slopes that apparently have never yet been visited by biologists. There is a reasonable possibility that some small mammal species presently unknown in Kentucky occur there.

An effort should be made to determine the complete range of *Clethrionomys gapperi maurus*, and to preserve several selected pieces of its habitat. That mouse should be on the official list of "Rare and Endangered Species of the United States" (subspecies are included on the list), and has recently been proposed.

There is little that we can do individually toward saving these biological treasures except express our concern. We would like to encourage efforts by the Nature Conservancy to acquire some of Kentucky's high country and to encourage the cooperation of the corporate land owners in saving the area. We welcome the interest of the Kentucky Nature Preserves Commission. We hope that enough concern is being generated to save these mountains.

LITERATURE CITED

BARBOUR, R. W. 1941. A preliminary list of the summer birds of the summit of Big Black Mountain. Ky. Warbler 17:46–47.

———— 1950a. The reptiles of Big Black Mountain, Harlan County, Ky. Copeia 1950 (2):100–107.

———— 1950b. A new subspecies of the salamander, *Desmognathus fuscus*. Copeia 1950 (4):277–278.

———— 1950c. Notes on the plants of Harlan County, Ky. Castanea 15:125.

———— 1951. The mammals of Big Black Mountain, Harlan County, Kentucky. J. Mammal. 32:100–110.

———— 1952. Animal habitats on Big Black Mountain. Trans. Ky. Acad. Sci. 13:215–220.

———— 1953. The amphibians of Big Black Mountain, Harlan County, Kentucky. Copeia 1953(2):84–89.

————, AND C. E. SMITH. 1956. *Pitymys pinetorum carbonarius* in Harlan County, Kentucky. J. Mammal. 37:121.

BRAUN, E. L. 1940. An ecological transect of Black Mountain, Kentucky. Ecol. Monogr. 10:193–241.

———— 1941a. The red azalea of the Cumberlands. Rhodora 43:31–35.

———— 1941b. Notes on Kentucky plants III. Castanea 6:10–12.

———— 1942. Notes on Kentucky plants VI. Castanea 7:7–10.

BREIDING, G. H. 1947. A list of birds from Big Black Mountain. Ky. Warbler 23:37–40.

CROFT, J. E. 1969. Notes from the southeastern mountains. Ky. Warbler 45:67–81.

GUILDAY, J. E., H. W. HAMILTON, AND A. D. MCCRADY. 1971. The Welch Cave peccaries

(*Platygonus*) and associated fauna, Kentucky Pleistocene. Ann. Carnegie Mus. 43:249–320.

KELLOGG, R. 1939. A new red-backed mouse from Kentucky. Proc. Biol. Soc. Wash. 52: 37–40.

LOVELL, H. B. 1950. Breeding birds of Big Black Mountain. Ky. Warbler 26:57–66.

MENGEL, R. 1965. The birds of Kentucky. Amer. Ornith. Union, Ornith. Monogr. No. 3. 581 pp.

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New Distributional Records for the Rosyside Dace in Kentucky

LEWIS GILES MILLER
Hunter Hancock Biological Station,
Department of Biological Sciences,
Murray State University, Murray, Kentucky 42071

ABSTRACT

The distribution of the rosyside dace *Clinostomus funduloides* includes the Tennessee River drainage of Kentucky. In view of collection records, the Blood River drainage of eastern Calloway County, Kentucky, appears to mark the farthest downstream distribution of the rosyside dace in the Tennessee River system. Information pertaining to ecology and associated species is also presented.

Branson (1977) and Clay (1975) reported the rosyside dace *Clinostomus funduloides* as being restricted, in Kentucky, to the Big Sandy and Little Sandy rivers and Tygart's and Kinniconick creeks.

Collection records indicate *Clinostomus funduloides* occurs widely in the Tennessee River system except in the extreme lower section in Kentucky (Bauer pers. comm.; Evermann 1918; Ross and Carico 1963; Jones 1974, unpublished master's thesis, Murray State University, Murray, Kentucky). Sisk (pers. comm.) collected *Clinostomus funduloides* from Billie Branch, a tributary to Cypress Creek on the Kentucky–Tennessee state line.

This paper presents information on the distribution of *Clinostomus funduloides* in the Tennessee River drainage of Kentucky along with information on its ecology and associated species.

Of the 13 sites sampled, 10 were within the Blood River drainage (Fig. 1). Blood River heads in north-central Henry County, Tennessee, and flows approximately 21.4 km north-northeast to empty into Blood River Embayment on the western side of Kentucky Lake (Tennessee River). The streams sampled in eastern Calloway County flow through an area known as the Breaks and are underlain by Cretaceous deposits of the Tuscaloosa, Eutaw, and Ripely series. Bedrock consists of Fort Payne, Warsaw, and St. Louis limestones. Streams west of the Breaks area of the Jackson Purchase are generally sluggish, turbid, underlain by Tertiary deposits, and are typical of Gulf Coastal Plain streams.

Streams were sampled from June through August 1977 with a habitat seine faced with mosquito mesh netting. Fishes were preserved in 10 percent formalin. Specimens are deposited in the Murray State University Vertebrate Museum.

Measurements of alkalinity, total hardness, and turbidity were made with a Hach

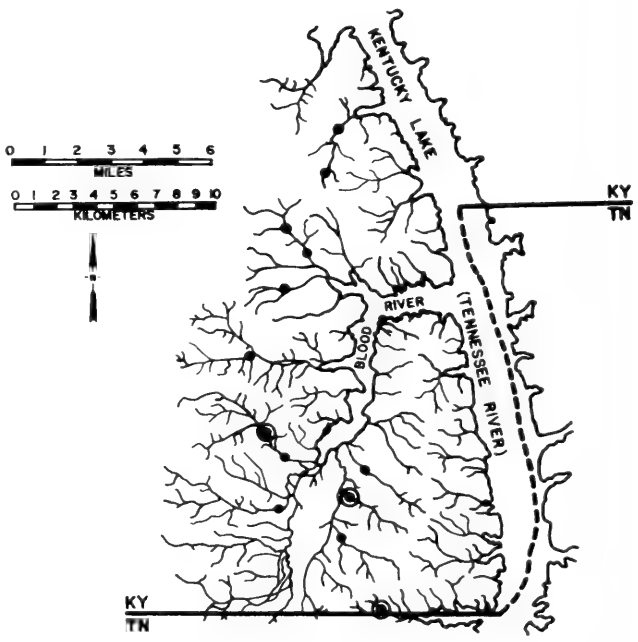

FIG. 1. Map of the western tributaries of the ascending arm of the Tennessee River in Calloway County, Kentucky, showing collection localities (dots). Localities from which *Clinostomus funduloides* was taken are circled.

TABLE 1.—PHYSICOCHEMICAL MEASUREMENTS OF STREAMS FROM WHICH ROSYSIDE DACE WERE COLLECTED

Station	Dissolved oxygen	pH	Methyl red-bromcresol green alkalinity	Total hardness	Specific conductivity μmhos/cm	Turbidity (JTU)	Water temp (C)
Panther Creek	7.0	6.3	10.0	10.0	38	38	19.0
Knight Branch	6.9	6.6	15.0	5.0	31	8	25.5
Billie Branch	6.3	6.3	15.0	10.0	30	42	23.0

chemistry kit. Measurements of dissolved oxygen and water temperature were taken with a Yellow Springs oxygen meter; pH was determined with a Hellige pH colorimeter; conductivity was registered using a Hach conductivity meter. All chemistry parameters were measured in the field.

Physicochemical measurements for streams from which rosyside dace were collected were little different than for streams from which they were not. Stream pH was slightly acidic; the water was soft and not well buffered (Table 1). Phenolphthalein alkalinity was zero. Methyl red–bromcresol green alkalinity never exceeded 20 mg/l. Conductivity rarely exceeded 40 μmhos/cm. Stream turbidity usually was not above 40 Jackson turbidity units. Pools from which the rosyside dace was taken were clear and had a bluish cast.

Clinostomus funduloides appeared to select a well-defined habitat in pools varying from 1.2 to 2.1 m wide and from 0.8 to 1.0 m deep. The substrate was sand and gravel with little or no silt; current was moderate at each site.

On 3 June 1977, 8 specimens of rosyside dace were collected from Panther Creek, a tributary to Blood River, 1.6 km upstream from Kentucky Highway 280 and 0.6 km downstream from Culpepper Hollow. The site was 4.2 km northwest of New Concord, Kentucky, and just downstream from the Trumann Bean farm.

On 11 August 1977, 3 specimens of rosyside dace were collected from Knight Branch, a tributary to Blood River, at the Bizzel Road Bridge 0.5 km south of Kentucky Highway 444 and 3.4 km east of New Concord, Kentucky.

On 15 August 1977, several specimens of rosyside dace were collected (1 specimen preserved) from Billie Branch, a tributary to Cypress Creek 0.3 km upstream from the Kentucky–Tennessee state line and 1.6 km west of Kentucky Highway 121. The site was 4.2 km southeast of New Concord, Kentucky, on the Terry Shoemaker farm.

Headwater species frequently associated with *Clinostomus funduloides* were the creek chub *Semotilus atromaculatus*, fantail darter *Etheostoma flabellare lineolatum*, spottail darter *Etheostoma squamiceps*, and snubnose darter *Etheostoma* (*Ulocentra*) sp. (Table 2). *Rhinichthys atratulus*, the blacknose dace, was taken only in Billie Branch; Jones (pers. comm.) found the rosyside dace and blacknose dace associated in the headwaters of Lost Creek, Land Between the Lakes, Tennessee, where they were uncommon. The goldstripe darter *Etheostoma parvipinne* is listed provisionally with associated species from Billie Branch. Sisk (pers. comm.) collected 2 specimens from that stream; however, none was collected during this study. Sisk's collection of *Etheostoma parvipinne* marks the first record of that etheostomid from Kentucky waters. The goldstripe darter has been recorded from Cypress Creek, Tennessee (Bauer pers. comm.).

Clinostomus funduloides appears to have evolved in the eastern Appalachians (Trautman 1957). The subspecies *Clinostomus funduloides estor* (Deubler 1955, unpublished doctoral dissertation, Cornell University, Ithaca, New York) apparently migrated down the Tennessee River during the Pliocene much as did *Etheostoma*

TABLE 2.—SPECIES ASSOCIATED WITH *Clinostomus funduloides*. (LETTERS IN PARENTHESES INDICATE STREAM: P = PANTHER CREEK, K = KNIGHT BRANCH, B = BILLIE BRANCH; LETTERS FOLLOWING REFER TO OCCURRENCE: C = COMMON, SEVERAL SPECIMENS BEING TAKEN, P = PRESENT BUT NOT COMMON, R = RARE, ONLY 1 OR 2 SPECIMENS)

Cyprinidae	
Semotilus atromaculatus	(P, K, B) C
Rhinichthys atratulus	(B) P
Cyprinodontidae	
Fundulus olivaceous	(P) R
Centrarchidae	
Lepomis megalotis	(K, B) P
Percidae	
Etheostoma flabellare	(P, K) C
E. parvapinne	(B) R*
E. squamiceps	(P, K, B) C
E. (*Ulocentra*) sp.	(P, K, B) C

* Present but not collected during this study (Sisk pers. comm.).

blennioides newmanii; the Tennessee River is thought to have been in a downcutting stage at that time, and velocity, depth, and turbidity probably were much different than at present (Miller 1968).

In view of collection records for streams in the Tennessee River drainage and from records of adjacent states, the streams from which *Clinostomus funduloides* was taken during this study apparently represent its farthest downstream distribution in the system (Bauer pers. comm., Buchanan 1973, Forbes and Richardson 1920, Jones unpublished master's thesis, Pflieger 1975, Sisk 1969, Smith and Sisk 1969, Sliger pers. comm., and Webb and Sisk 1975).

Increased agrarian land use in the Breaks area of eastern Calloway County, with its accompanying siltation, presents a growing threat of habitat destruction to the few remaining populations of the rosyside dace in the Tennessee River drainage of Kentucky.

Special thanks are due Bruce Bauer, Tennessee Wildlife Resources Agency, and Dr. Andrew Sliger, University of Tennessee, Martin, for providing collection records. Thanks are also due the late Dr. Morgan E. Sisk who generated my interest in fishes and who early stimulated this study. My thanks also go to Mike Freeze, Judy Harrer, and Rick Morin without whose assistance in the field this study would not have been possible.

LITERATURE CITED

BRANSON, B. A. 1977. Threatened fishes of Daniel Boone National Forest, Kentucky. Trans. Ky. Acad. Sci. 38(1–2):69–73.

BUCHANAN, T. M. 1973. Key to the fishes of Arkansas. Ark. Game Fish Comm., Little Rock, Ark. 177 pp.

CLAY, W. M. 1975. The fishes of Kentucky. Ky. Dept. Fish Wildl. Res., Frankfort, Ky. 416 pp.

EVERMANN, B. W. 1918. The fishes of Kentucky and Tennessee. A distributional catalogue of the known species. Bull. U.S. Bur. Fish. 35:295–368.

FORBES, S. A., AND R. E. RICHARDSON. 1920. The fishes of Illinois. Ill. Nat. Hist. Surv., 2nd ed. 358 pp.

MILLER, R. V. 1968. A systematic study of the greenside darter, *Etheostoma blennioides* Rafinesque (Pisces: Percidae). Copeia 1968 (1):1–40.

PFLIEGER, W. L. 1975. The fishes of Missouri. Mo. Dept. Cons., Jefferson City, Mo. 343 pp.

ROSS, R. D., AND J. E. CARICO. 1963. Records and distribution problems of fishes of the North, Middle, and South Forks of the Holston River, Virginia. Va. Agr. Exp. Sta. Bull. 161:1–24.

SISK, M. E. 1969. The fishes of West Kentucky. I. Fishes of Clark's River. Trans. Ky. Acad. Sci. 30(3–4):54–59.

SMITH, P. L., AND M. E. SISK. 1969. The fishes of West Kentucky. II. The fishes of Obion Creek. Trans. Ky. Acad. Sci. 30(3–4):60–68.

TRAUTMAN, M. B. 1957. The fishes of Ohio. Ohio St. Univ. Press., Columbus, Ohio. 683 pp.

WEBB, D. H., AND M. E. SISK. 1975. The fishes of West Kentucky. III. The fishes of Bayou de Chien. Trans. Ky. Acad. Sci. 36(3–4): 63–70.

Trans. Ky. Acad. Sci., 39(3–4), 1978, 145–146

Habitat of the Golden Mouse *Ochrotomys nuttalli*

Wayne H. Davis and Charles K. Smith
School of Biological Sciences,
University of Kentucky, Lexington, Kentucky 40506

Abstract

In the autumn and winter of 1977–1978, during an apparent population high at Cumberland Gap National Historical Park, Kentucky, *Ochrotomys nuttalli* became established in habitats not usually associated with it. The mice were found in an area devoid of trees and in an area where the ground cover was grass, lacking shrubs or vines. A colony is established in a thicket of *Rhododendron maximum* L. in a hemlock and hardwood forest along Shillalah Creek at Hensleys Settlement at 3,240 feet (997 m) elevation on Cumberland Mountain.

The favored habitat of the golden mouse *Ochrotomys nuttalli* is a dense tangle of vines climbing up among trees. Such areas are typical of moist lowlands, dry hillsides, woodland borders, and areas of secondary growth in the southeastern United States.

Thickness of the understory appears to be the most important factor (McCarley 1958, Goodpaster and Hoffmeister 1954). Vines such as greenbrier (*Smilax*), honeysuckle (*Lonicera*), and grape (*Vitis*), provide best cover, although blackberries (*Rubus*) are satisfactory. Trees preferred are cedars and pines (Barbour 1942, 1951; Barbour and Davis 1974; Linzey 1968; Wallace 1969). Golden mice are semi-arboreal, building nests and feeding platforms up among the vines and trees (Goodpaster and Hoffmeister 1954).

Howell (1921) and Handley (1948) noted the occurrence of golden mice in canebrakes in Alabama and Virginia. In Florida, Pearson (1953) found them restricted to densely shrubby areas in hammocks, but Ivey (1949) found them common in hammocks where magnolias shaded out nearly all the understory, as well as in the brushy hammock edges.

In the course of our work on a survey of the mammals of Cumberland Gap National Historical Park, we found golden mice in a variety of habitats, some of which seem unusual.

During the fall of 1977, we trapped several golden mice in a flat lowland area devoid of trees below the Visitors' Center. The mice were taken where Japanese honeysuckle (*Lonicera japonica* Thunb.) formed a dense mat covering the ground, nearly excluding all other plant life. On 26 November 1977, we caught a pair of golden mice in the same area in a patch of golden rod (*Solidago*) with an understory of grass. Nearby were 2 white pines (*Pinus strobus* L.) and a yellow pine (*Pinus echinata* Mill.), all of which were devoid of undergrowth.

From 5–7 January 1978, we captured 7 *Ochrotomys nuttalli* in 35 traps set along Shillalah Creek at Hensleys Settlement near the summit of Cumberland Mountain at an elevation of 3,240 feet (997 m). The vegetation consisted of large forest trees (oak, maple, hemlock) with the understory almost exclusively *Rhododendron maximum* L. The golden mice were caught among the fallen logs and rhododendron, a habitat they shared with red-backed mice *Clethrionomys gapperi maurus*), cloudland deer mice (*Peromyscus maniculatus nubiterrae*), and wood mice (*P. leucopus*).

Barbour (1951) made an intensive survey of the mammals of the nearby Big Black Mountain and found no golden mice above 2,700 feet (823 m). He concluded that they seemed to be restricted to the valleys and lower slopes, brush-covered areas where *Smilax* was much in evidence.

In the Great Smoky Mountains, golden mice have been found only in the foothills,

ranging up to 2,700 feet elevation and were never taken in the rhododendron thickets (Linzey and Linzey 1971). Although Odum (1949) found golden mice ranging up to 4,120 feet (1,256 m) near Highlands, North Carolina, and captured 1 specimen among rhododendrons, we suspect that their invasion of the rhododendrons atop Cumberland Mountain in southeastern Kentucky is a recent development.

Perhaps a high population of golden mice in the Cumberland Gap area has caused some individuals to move into marginal habitats. Although they seem well established in the rhododendrons at this time, it will be interesting to see if they persist.

LITERATURE CITED

BARBOUR, R. W. 1942. Nest habitat of the golden mouse in eastern Kentucky. J. Mammal. 23(1):90–91.

———. 1951. The mammals of Big Black Mountain, Harlan County, Kentucky. J. Mammal. 32(1):100–110.

——— AND W. H. DAVIS. 1974. Mammals of Kentucky. Univ. Press Ky., Lexington, Ky. 322 pp.

GOODPASTER, W. W., AND D. F. HOFFMEISTER. 1954. Life history of the golden mouse, *Peromyscus nuttalli*, in Kentucky. J. Mammal. 35(1):17–27.

HANDLEY, C. O., JR. 1948. Habitat of the golden mouse in Virginia. J. Mammal. 29(3):298–299.

HOWELL, A. H. 1921. A biological survey of Alabama. U.S. Dept. Agric., Bur. Biol. Surv., N. Amer. Fauna No. 45: 1–88.

IVEY, R. D. 1949. Life history notes on three mice from the Florida east coast. J. Mammal. 30(2):157–162.

LINZEY, A. V., AND D. W. LINZEY. 1971. Mammals of Great Smoky Mountains National Park. Univ. Tenn. Press, Knoxville, Tenn. 114 pp.

LINZEY, D. W. 1968. An ecological study of the golden mouse, *Ochrotomys nuttalli*, in the Great Smoky Mountains National Park. Amer. Midl. Nat. 79(2):321–345.

MCCARLEY, H. 1958. Ecology, behavior and population dynamics of *Peromyscus nuttalli* in eastern Texas. Texas J. Sci. 10:147–171.

ODUM, E. P. 1949. Small mammals of the Highlands (North Carolina) Plateau. J. Mammal. 30(2):179–192.

PEARSON, P. G. 1953. A field study of *Peromyscus* populations in Gulf Hammock, Florida. Ecology 34:199–207.

WALLACE, J. T. 1969. Some notes on the growth, development and distribution of *Ochrotomys nuttalli* (Harlan) in Kentucky. Trans. Ky. Acad. Sci. 30(1–2):45–52.

Trans. Ky. Acad. Sci., 39(3–4), 1978, 147–149

Index Herbariorum Kentuckiensis

Stuart Lassetter
Department of Biological Sciences, Eastern Kentucky University,
Richmond, Kentucky 40475

Abstract

A survey conducted during the spring of 1977 indicates 10 institutional herbaria and 2 private herbaria in Kentucky. More than 119,000 specimens are contained in those 12 herbaria.

Herbaria of Kentucky

Except for the few herbaria listed in Holmgren and Keuken (1974), relatively little information concerning Kentucky herbaria is available. The survey information presented herein is offered as a reference for herbarium resources in Kentucky.

A list of 38 colleges and universities was compiled from Hurt (1975). Technical and business schools as well as theological seminaries were excluded, but state and private schools and community colleges were contacted. My gratitude is extended to those persons who took time to return the questionnaires.

Results of this survey show 10 institutional herbaria and 2 private herbaria in Kentucky. All are small, but in combination they represent more than 119,000 plant specimens.

Each herbarium with its factual material is listed below. If the herbarium is listed in Holmgren and Keuken (1974) the Index Herbariorum symbol follows the herbarium name.

Asbury College Herbarium

Division of Science and Mathematics, Asbury College, Wilmore, Kentucky 40390.
Henry H. Howell, Curator.
Established 1967.
Number of specimens not given, vascular plants and lichens.
No active accession or exchange.

Athey Herbarium (private collection)

701 Woodland Drive, Paducah, Kentucky 42001.
Raymond Athey, Curator.
Established 1967.
3,671 unmounted vascular plants (mostly Compositae, Gramineae, and Cyperaceae of prairie habitats) and some bryophytes; duplicates in Memphis State University Herbarium.
Active accession, no active exchange, no loans.

Berea College Herbarium

Berea College, Berea, Kentucky 40404.
James Grossman, Curator.
No establishment date given.
560 vascular plants from Berea College Forest lands.
No active accession, no exchange.

Centre College Bryophyte Herbarium

Division of Science and Mathematics, Centre College, Danville, Kentucky 40422.
Susan M. Moyle, Curator.
Established 1974.
200 temperate zone bryophytes, many from Red River Gorge.
Active accession, active exchange (outgoing = Kentucky bryophytes; incoming = temperate zone bryophytes).

Davies Herbarium (DHL)

Department of Biology, University of Louisville, Louisville, Kentucky 40208.
W. S. Davis, Curator; Harry Woodward.
Establishment date not given.
22,000 vascular plants (some bryophytes, lichens, fungi, and algae).

Important collections from Bernheim Forest, Kleeber Bird Sanctuary, Horner Wildlife Sanctuary, and some type specimens.

Active accession and exchange (outgoing = vascular plants, flowering plants; incoming = vascular plants, flowering plants).

Eastern Kentucky University Herbarium

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475.

Stuart Lassetter, Curator; William H. Martin.

Established 1974.

3,300 vascular plants.

Active accession and active exchange (outgoing = vascular plants mostly of Kentucky and southeastern United States; incoming = *Vicia*, and general vascular plant collections).

Herbarium of Biology Department

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101.

Kenneth A. Nicely, Curator; Ernest O. Beal.

Established 1967.

9,058 (plus 1,000 in processing) vascular plants (about half are local and Western Kentucky specimens, and half are duplicates of Flora of the Carolinas and southeastern United States).

Active accession, limited exchange (mainly exchange with Kentucky herbaria).

Herbarium of Thomas Hunt Morgan School of Biological Sciences (KY)

Thomas Hunt Morgan School of Biological Sciences, University of Kentucky, Lexington, Kentucky 40503.

S. F. Conti, Director; Willem Meijer, Curator.

Reestablished in 1948 after fire destroyed previous collections.

39,603 vascular plants, not including bryophytes and lichens.

Important collections: Dr. Short, 1840; county flora thesis collections for McLean County (J. Conrad) and Bourbon County (Edi Gudharji).

Active accession and exchange (outgoing = vascular plants of Kentucky and adjacent areas; incoming = Eastern United States flora).

Morehead State University Herbarium

Department of Biology, Morehead State University, Morehead, Kentucky 40351.

Howard L. Setser, Curator.

Establishment date unknown, specimens date from 1920's.

5,300 vascular plants.

Important collections: several McCoy Ferns of Kentucky specimens.

Active accession and exchange (outgoing = vascular plants of eastern Kentucky; incoming = vascular plants of Kentucky and adjacent states.

Murray State University Herbarium (MUR)

Department of Biological Sciences, Murray State University, Murray, Kentucky 42071.

Marian J. Fuller, Curator.

Established 1967.

14,000 vascular plants and some bryophytes.

Important collections: Thomas McCoy fern collection.

Active accession and exchange (outgoing = Kentucky vascular plants; incoming = vascular plants).

Northern Kentucky University Herbarium (KNK)

Department of Biological Sciences, Northern Kentucky University, Highland Heights, Kentucky 41076.

John W. Thieret, Curator.

Established 1973.

10,000 (plus 10,000 unmounted) vascular plants and a few lichens, some type specimens.

Active accession and active exchange (outgoing = vascular plants; incoming = vascular plants).

Varner Herbarium (private collection)

Route 3, Cynthiana, Kentucky 41031.
Johnnie B. Varner, Curator.
Established 1965.
11,583 vascular plants (Kentucky woody plants, *Crataegus*, southern Appalachian collections).
Active accession, no exchange, no loans.

In addition to these collections housed in Kentucky, there are regional herbaria near Kentucky that have a significant number of Kentucky specimens. They are Memphis State University, Memphis, TN; Southern Illinois University (SIU) in Carbondale, IL; University of Cincinnati (CINC) in Cincinnnati, OH; University of Tennessee (TENN) in Knoxville, TN; University of West Virginia (WVA) in Morgantown, W. VA.; and perhaps Marshall University in Huntington, W. VA. (Raymond Athey, Willem Meijer, Linda Rader, pers. comm.). The Reed Herbarium in Baltimore, MD also contains a great number of Kentucky specimens. The U.S. National Herbarium (US) in Washington, D.C. contains Lucy Braun's collections.

Historical collections by early botanists are housed in various American and European herbaria, but it is not the purpose of this paper to provide a complete list of those collections.

LITERATURE CITED

HOLMGREN, P., AND W. KEUKEN. 1974. Index herbariorum. Part I. The herbaria of the world. Sixth ed. Oosthoek, Scheltema, and Holkema, Utrecht, Netherlands. 397 pp.

HURT, H. W. 1975. The college blue book. 15th ed. Macmillan Publ. Co., Inc., New York, N.Y. 782 pp.

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The Fantail Darter *Etheostoma flabellare* in the Salt River Drainage, Kentucky

JOHN R. BAKER[1]
Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40208

ABSTRACT

Age and growth, length–weight relationship, coefficient of condition, food habits, sex ratios, and a maturity index were determined for the fantail darter *Etheostoma flabellare* in Brashears Creek, a tributary to the Salt River in Spencer and Shelby counties, Kentucky. Comparisons were made with other fantail darters collected throughout the Salt River Basin. Life span was approximately 2.5 years for males and 2 years for females. Growth was greatest in the first year from June through October. Coefficient of condition was highest in July and lowest in November. Food consisted of Diptera, Ephemeroptera, Trichoptera, Plecoptera, and other invertebrates in order of importance. Males were more numerous than females due to a differential mortality rate. The maturity index for females was highest in April when the ovary weight was 15.5 percent of the body weight.

INTRODUCTION

The fantail darter *Etheostoma flabellare* is a slender fish 30–60 mm long. Its back is olive brown and the sides are yellowish brown marked by dark horizontal streaks, with dark brown crossbars on the back, and with the tail prominently banded with dark brown lines. The fantail darter inhabits rocky and gravelly riffles of streams that range in size from small creeks to relatively large rivers and is widely distributed throughout the Mississippi drainage. It is more tolerant of turbidity and organic pollution than most darters. It feeds principally on immature stages of aquatic insects in the riffle habitat (Pflieger 1975). In the Salt River it is an important part of the fauna, being the second most abundant fish (Neff and Krumholz 1974) throughout the mainstream and most of the tributaries (Hoyt et al. 1970). In an effort to ameliorate periodic flooding, 3 impoundments were planned for the Salt River System. Those impoundments would eliminate much of the habitat of the fantail darter. Therefore, because of its importance as a major component of the fauna and the possibility of habitat loss, this study was undertaken to determine some of the biological aspects of the fantail darter within the Salt River System.

The Salt River drainage lies in the Outer Blue Grass Region of Kentucky. The rock strata are Ordovician limestone shale of the Maysville, Richmond, and Eden group containing up to 90 percent shale (Hendricksen and Krieger 1964). Due to the impervious nature of the shale, stream flow fluctuates drastically during periods of heavy precipitation, and is tremendously influenced by extensive beds of water willow *Justicia americana* (L.). Islands and embankments are formed from the accumulation of gravel and debris in the water willow diverting the flow back and forth across the stream bed developing pools and riffles that give the stream a braided appearance. Those beds also serve to maintain pool levels that are important to aquatic life, especially during periods of low rainfall in late summer and early fall. Physical and chemical aspects of the Salt River and its tributaries are given in Woodling (1971, unpublished master's thesis, University of Louisville, Louisville, Kentucky) and Miller (1976, unpublished doctoral dissertation, University of Louisville, Louisville, Kentucky).

[1] Present address: Department of Biological Sciences, University of Nevada, Las Vegas, Las Vegas, Nevada 89154.

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I wish to extend special thanks to Louis A. Krumholz for his guidance and encouragement throughout the course of the study and for his review of this manuscript. Deep appreciation is offered to Peter Bersell, Edmond J. Bacon, Jr., Daryl E. Jennings, Andrew C. Miller, and David S. White for their assistance in the field and in the laboratory, and to F. Bowsher for typing this manuscript.

METHODS

A total of 1,793 fantail darters was taken from 5 locations on Brashears Creek (Fig. 1, Stations 26–30) monthly from June 1972 through May 1973. No fish were collected in April due to high water. In addition, 295 fish were obtained from the following areas (Fig. 1): Salt River Stations 3, 11, and 14; Chaplin River Stations C2 and C10; Beech Fork, Marion County; West Fork of Simpson Creek, Nelson County; and Plum Creek, Spencer County. Sixteen fish were collected from Harrods Creek, Oldham County (not part of the Salt River drainage) in April and were used to supplement the data for that time period.

Collections were made with a 3-mm-mesh minnow seine. The fish were either shocked with an 1100-watt alternator or herded by kicking the riffles. Specimens were immediately fixed in 10 percent formalin and later preserved in 70 percent ethanol.

Standard length, weight, and sex were determined for all fish. After blotting each fish with a paper towel, they were weighed to the nearest 0.01 g on a Mettler single-pan electric balance and measured to the nearest millimeter. Sex was determined by examining the genital papillae; in males, the genital papilla narrows at the apex to a blunt point whereas in females it remains broad and expanded. That characteristic proved completely reliable with fish over 25 mm long. Smaller fish could not be sexed by that method, nor could they be sexed by dissection because of the lack of development of the gonads.

Length-frequency distributions were made for each collection, grouping the fish in 2-mm intervals. Age groups were determined using both scales and length frequencies. Scales from 80 fish of various length groups were examined for aging as outlined by Larimore (1957). The scales were removed from the left side of the body above the lateral line at the junction of the dorsal fins. The length–weight relationship and coefficient of condition values were determined according to formulas of Lagler (1969). The length–weight relationship for 127 fish from Brashears Creek was computed using the least squares method and is expressed in the logarithmic form:

$$\text{Log } W = 4.8650 + 3.0085 \text{ Log } L$$

where W equals weight in milligrams and L equals standard length in millimeters.

Food habits were determined using frequency of occurrence and average number of individual organisms per stomach (Lagler 1969). Four hundred stomachs (30–50 per month) were analyzed for their contents. Material from the intestine was not used. Identifications were based on keys by Burks (1953), Pennak (1953), Ross (1944), and Usinger (1956).

The ovaries from 176 fantail darters were removed and weighed to the nearest 0.1 g; 160 were from Brashears Creek collected in October through March and May and 16 were from Harrods Creek, Oldham County, collected in April.

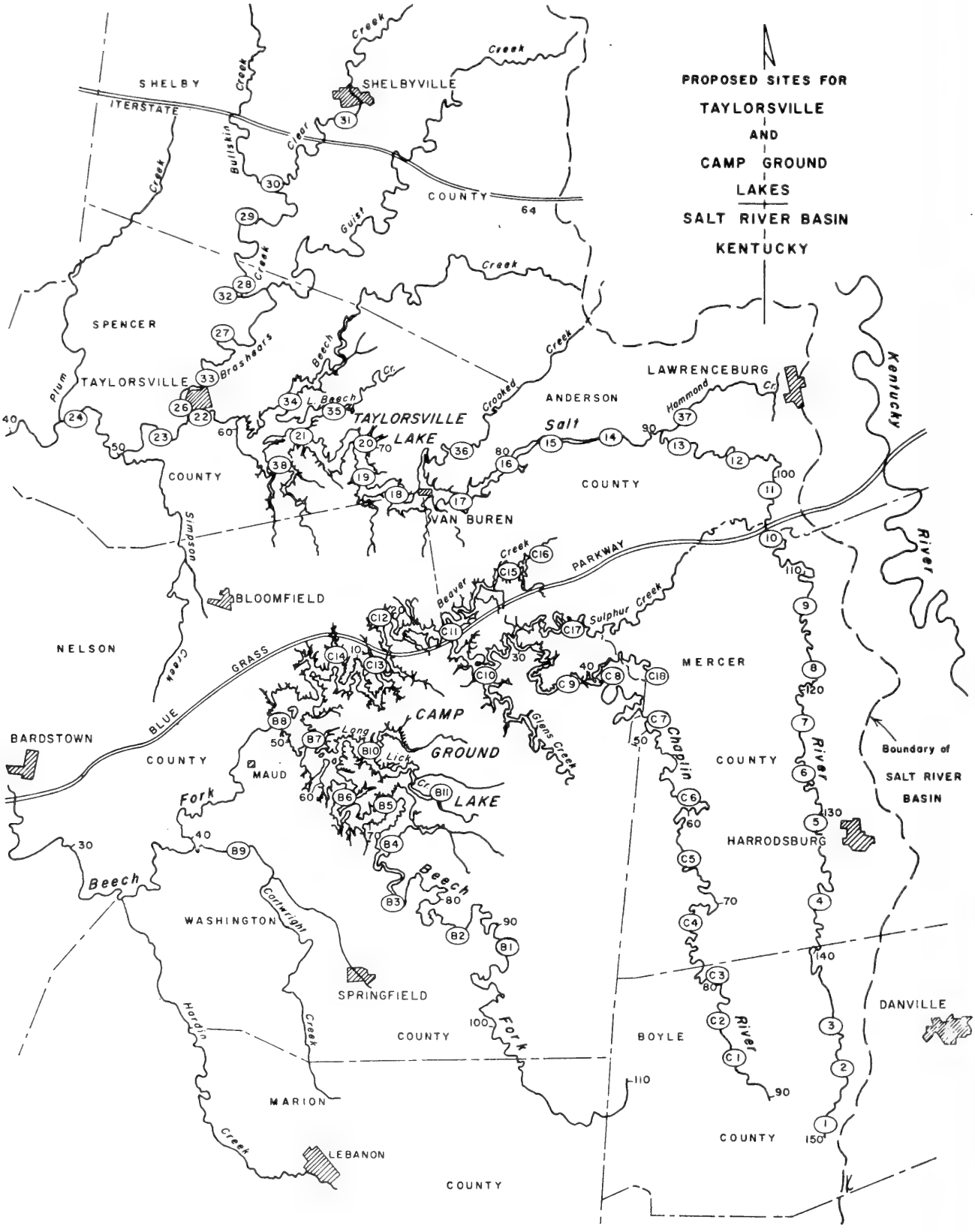

FIG. 1. Part of the Salt River Basin of Kentuckyshowing the locations of stations used as collecting sites (after Neff and Krumholz 1974).

RESULTS AND DISCUSSION

Associated Species

In July, an extensive collection was made in the riffle areas of Brashears Creek. At that time, 14 species of fishes were collected along with the fantail darter. *E. flabellare* was the most abundant fish constituting 62 percent of the collection. Other fishes in order of relative abundance were: *Etheostoma caeruleum, Etheostoma blennoides, Campostoma anomalum, Pimphales notatus, Etheostoma zonale, Noturus flavus, Notropis spilopterus, Hypentelium nigricans, Notropis ardens, Notropis stramineus, Notropis boops, Percina caprodes, Ericymba buccata,* and *Pimphales promelas.* Nomenclature follows Bailey et al. (1970).

Age and Growth

Age groups were readily distinguished from length–frenquency distribution (Fig. 2) after the spawning period in May and June. Scales were used for age determinations when age based on the length-frequency distribution was questionable. Age Groups 0, 1, and 2 were present in Brashears Creek and the Salt River. Only 3 females in Age Group 2 were collected at Brashears Creek and Salt River Station 3. The 2 largest females (50 mm) were collected in May and June; the largest male was 56 mm collected in October.

Schwartz (1965) reported that newly hatched fantail darters from the upper Allegheny River, Pennsylvania, averaged 7.3 mm total length, similar to the 7.0 mm reported by Lake (1936) from Black Creek, New York. Young-of-the-year fish from Brashears Creek had a mean standard length in June of 20 mm, almost 3 times the length of reported newly hatched fish (Fig. 3). After the first month, there was an increase of approximately 15 mm per year. At the end of 1 and 2 years, *E. flabellare* reached mean standard lengths of 35 and 51 mm, respectively. Males in Age Group 1 were slightly larger than females, mean lengths being 36 mm and 34 mm, respectively. Winn (1958a) reported "males larger" as a sexual dimorphic characteristic in fantail darters but did not report the extent of dimorphism. In the Salt River, size is not a readily distinguishable sexual dimorphic characteristic for fantail darters.

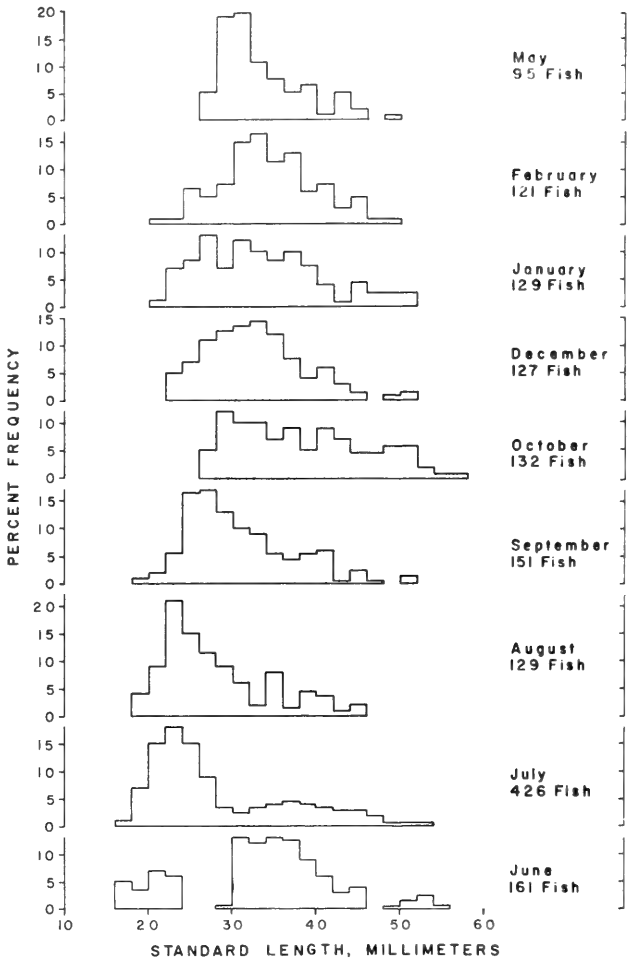

FIG. 2. Length frequencies of fantail darters from Brashears Creek, 1972 and 1973. The earliest collection (June) is at the bottom of the figure.

Karr (1964), using the scale method, reported for *E. flabellare* from Bluff Creek, Iowa, total lengths of 18.7, 34.8, and 42.4 mm at the first through the third annuli, respectively, for females, and males were 18.5, 36.7, 59.0, and 62.0 mm at the first through the fourth annuli, respectively. Lake (1936) reported fantail darters of Age 0 to be about 30 mm standard length in November after hatching in June, similar to that for fantail darters in Brashears Creek. Scales did exhibit an area in the first year of growth where the distance between circuli was increased. Such ex-

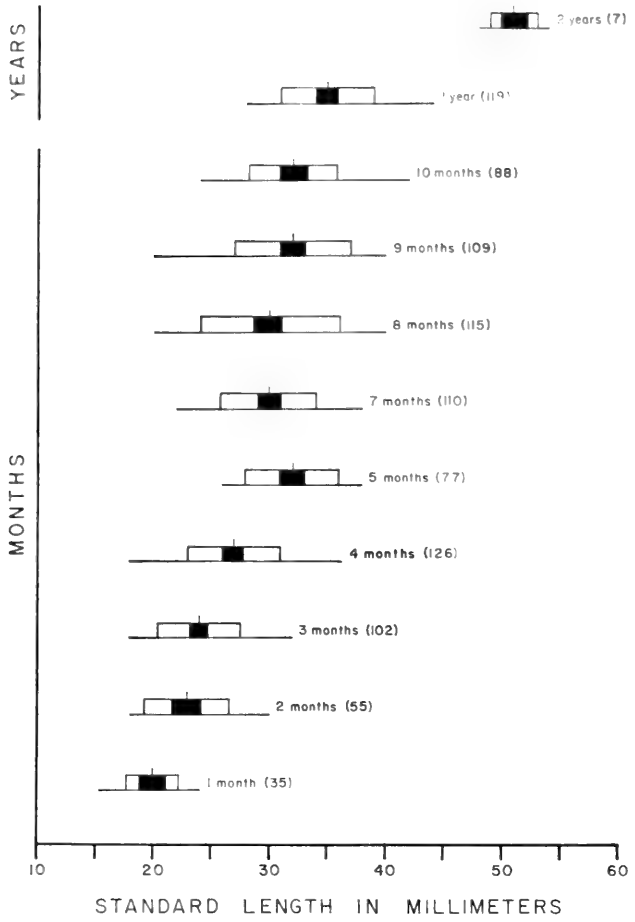

FIG. 3. Mean standard lengths of fantail darters at different ages in Brashears Creek, 1972 and 1973. The baseline for each age group is the range in standard length, the open rectangle is 1 standard deviation to each side of the mean, and the closed rectangle is 2 times the standard error to each side of the mean. Numbers in parentheses are numbers of specimens.

panded circuli may have been mistaken by Karr for annuli.

Condition Factor

The coefficient of condition or condition factor, K, was determined monthly for males and females of Age Groups 0 and 1 (Fig. 4). Since sex of fish in Age Group 0 could not be determined in June and July, those specimens were lumped together. The condition factor in all groups was highest in July and declined through November. Females of both age groups had higher K values than males due to increasing ovarian weights in December–February but dropped below males in May after spawning. Unfortunately, adequate

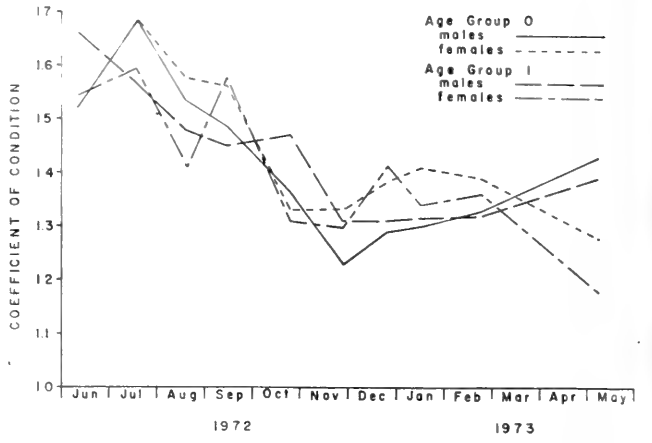

FIG. 4. Seasonal changes in the coefficient of condition, $K \times 10^5$, for male and female fantail darters of Age Groups 0 and 1 from Brashears Creek, 1972 and 1973. K values for March and April were not determined.

collections could not be made in March and April because of high water. Females probably would have shown a high K value in early April when ovaries were at their greatest development. Weights of males apparently were not affected by reproduction as Tsai (1972) has shown for *Etheostoma olmstedi*, although K values for March and April may have reflected some change. The condition factor did decrease with age. K values for Age Group 2 males in June and July were 1.332 and 1.380, respectively, considerably lower than for Age Group 0 or 1 during the same time period (Fig. 4).

The condition factor varies with both environmental as well as biological factors. Of those environmental factors that have an effect, the available food supply is of major importance. The primary food of the fantail darter is immature aquatic insects. In Brashears Creek, Woodling (unpublished thesis) found the lowest average biomass and average number of organisms in June through August. The condition factor for *E. flabellare* was highest during that period indicating that benthic organisms even at their lowest level were present in sufficient numbers to provide an adequate food supply. Decreasing water temperatures in August–November appeared to have the greatest effect on the condition factor, with the lowest value,

TABLE 1.—COEFFICIENT OF CONDITION, K × 10^5, FOR FANTAIL DARTERS FROM 9 STATIONS IN THE SALT RIVER DRAINAGE. NUMBERS IN PARENTHESES INDICATE NUMBERS OF SPECIMENS. SEE FIG. 1 FOR LOCATIONS OF STATIONS

Station	Date	Coefficient of condition
Plum Creek	30 May	1.6238 ± .0305 (12)
Brashears Creek	13 Jun	1.5370 ± .0309 (37)
Simpson Creek	31 May	1.4610 ± .0272 (50)
Chaplin River, C2	21 May	1.4231 ± .0177 (40)
Chaplin River, C10	10 Jun	1.3951 ± .0213 (40)
Salt River, 14	24 Jul	1.3894 ± .0410 (50)
Salt River, 11	29 Jun	1.3046 ± .0160 (50)
Salt River, 3	21 May	1.2870 ± .0536 (4)
Beech Fork	5 Jun	1.0882 ± .0828 (5)

except for females in May, occurring in November corresponding with low water temperatures. The increasing condition factor in December through March corresponded with increasing water temperature and gonadal weight.

Condition factors for fish collected throughout the Salt River system at approximately the same time and of the size group are shown in Table 1. The lowest condition factor was in those fish from the headwaters of Beech Fork of the Chaplin River, a major tributary to the Salt River. In the Salt River mainstream, K values increased from the headwater downstream with the highest value occurring in Plum Creek, a small intermittent tributary to the Salt River. The condition factor of those fish from the Chaplin River mainstream were intermediate to those of the Beech Fork and Salt River. The reason for such a gradual increase in condition factor from upstream to downstream in samples from the Salt River and the low value in Beech Fork are not obvious but must be related to environmental factors.

Food Habits

Analysis of the contents of 400 fantail darters from Brashears Creek revealed that aquatic insects, isopods, and amphipods were the only food items taken (Table 2). Dipterans (primarily chironomids) were

TABLE 2.—SEASONAL DIFFERENCES IN STOMACH CONTENTS OF FANTAIL DARTERS AS PERCENTAGE FREQUENCY OF OCCURRENCE, BRASHEARS CREEK, 1972 AND 1973. NUMBERS IN PARENTHESES INDICATE AVERAGE NUMBERS OF ORGANISMS PER STOMACH

Taxonomic group	Jun	Jul	Aug	Sep	Oct
Ephemeroptera	73(3.5)	47(1.3)	47(3.0)	41(3.5)	30(1.4)
Plecoptera			3(1.0)		
Lepidoptera	6(1.0)	3(1.0)			
Coleoptera	10(2.0)	3(1.0)	6(1.0)	6(1.0)	2(1.0)
Trichoptera	63(3.7)	60(2.2)	40(3.2)	31(2.3)	20(1.5)
Diptera	57(8.2)	50(3.9)	50(1.7)	59(4.9)	45(4.3)
Isopoda			3(1.0)		2(3.0)
Amphipoda					

Taxonomic group	Nov	Dec	Jan	Feb	Mar	May
Ephemeroptera	17(1.0)	4(1.0)	2(1.0)	6(1.0)	87(1.9)	37(1.1)
Plecoptera	12(1.7)	51(3.2)	29(1.4)	20(1.4)	12(1.0)	27(1.3)
Lepidoptera						
Coleoptera						
Trichoptera		2(1.0)	2(1.0)	2(1.0)		23(2.3)
Diptera	63(5.7)	62(8.4)	82(14.7)	82(14.7)	100(10.3)	39(9.2)
Isopoda	4(1.0)	11(1.4)	6(1.3)	6(1.3)		50(4.6)
Amphipoda	4(1.0)	11(1.2)	2(1.0)	4(1.5)		5(2.5)

TABLE 3.—STOMACH CONTENTS OF FANTAIL DARTERS AS PERCENTAGE FREQUENCY OF OCCURRENCE IN LENGTH GROUPS 1 (25–35 MM, N = 208), 2 (36–45 MM, N = 158), AND 3 (46–55 MM, N = 34), BRASHEARS CREEK, 1972 AND 1973. NUMBERS IN PARENTHESES INDICATE AVERAGE NUMBERS OF ORGANISMS PER STOMACH

	Length group of darters		
Taxonomic group	1	2	3
Ephemeroptera	36 (2.5)	24 (2.3)	32 (2.4)
Plecoptera	18 (2.0)	24 (2.8)	18 (2.2)
Lepidoptera	2 (1.0)	2 (1.0)	
Coleoptera	3 (1.5)	3 (1.4)	
Trichoptera	25 (2.1)	30 (3.2)	32 (3.0)
Diptera	66 (6.4)	49 (8.5)	47 (14.4)
Isopoda	10 (4.3)	10 (2.4)	3 (3.0)
Amphipoda	3 (1.8)	3 (1.0)	

the most important food throughout the year. Mayflies (Ephemeroptera) were the only other insects utilized throughout the year although they were not abundant in winter when stoneflies (Plecoptera) were a major food item (December through February). Caddisflies (Trichoptera) and mayflies were important summer food items (June through October). Aquatic moth larvae (Lepidoptera) and aquatic beetle larvae (Coleoptera) made up a small portion of summer food. Isopods and amphipods also were utilized as winter food.

There was no apparent selectivity of food items. Dominant food items corresponded with dominant benthic organisms reported by Woodling (unpublished thesis) for Brashears Creek. Larval chironomids and mayflies (*Stenonema* spp.) were available throughout the year and were utilized accordingly. Other food items were taken as they became available. There was also no selection of food items by different size groups of darters (Table 3). Smaller fish used the same size food items as larger fish, but there were no lepidopterans, coleopterans, or amphipods in the stomachs of large fish. This probably was due to the infrequent occurrence of those organisms and the small sample size for the larger fish.

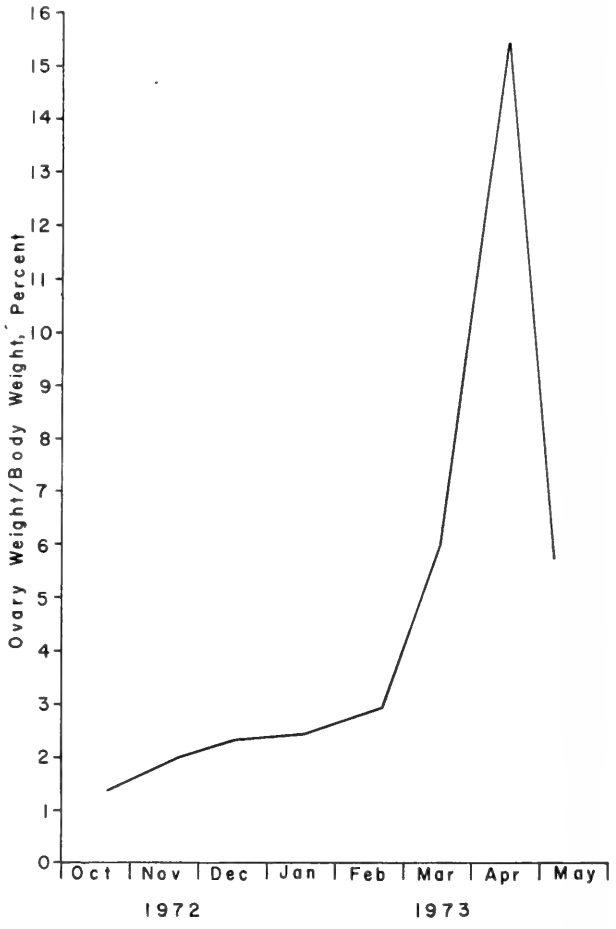

FIG. 5. Maturity index for female fantail darters based on specimens from Brashears Creek and Harrods Creek, 1972 and 1973.

Reproduction

The maturity index (percentage of ovarian weight to body weight) for fantail darters in Brashears Creek indicated that spawning occurred in April and early May (Fig. 5). Again, data for fish from Harrod's Creek were used in April because there was no collections for that month from the Salt River. On 7, 15, and 18 May, the maturity index was 5.8, 6.4, and 9.5, respectively. The 7 May collection was taken from the swifter riffles in the mainstream and had a higher number of spent individuals. Ovarian weights were higher in fish collected on 5 and 18 May from along the banks and side streams where current was moderate. A number of nests were found along the banks and side streams indicating that those areas were the primary spawning grounds. Side

streams and banks apparently were selected by the fantail darter because of slower current and higher water temperature. Water temperatures in those areas were 1–2 C higher than in the mainstream where the average temperature was 17 C on 15 May. Winn (1958a) reported that *E. flabellare* spawned the first week of April in Kentucky and Tennessee and about 2 weeks later in Michigan. Lake (1936) reported spawning in Black Creek, New York, from 26 April to 22 June with incubation for about 21 days at 70 F (21 C).

The breeding habits of *E. flabellare* have been described by Lake (1936) and Winn (1958a, 1958b). They reported that the nest is prepared on the undersides of rocks and guarded by the male. An acceptable female enters the nest, turns upside down, and deposits the eggs by attaching them to the lower surface of the rock as they are fertilized by the male. Usually, about 45 eggs are deposited one at a time and the female stays in the inverted position for the entire egg laying period, approximately 2 hours. Males usually assume the inverted position only at the moment of deposition of an egg. Females are reproductively active during their first year of life. A large female may spawn 5 times during a spawning season and several females may spawn in the same nest. The male remains in the nest until the eggs hatch and keeps them free from silt and fungus by cleaning them with the bulbous pads developed on the dorsal fin.

The breeding habits of *E. flabellare* and *E. nigrum* are very similar, and Winn (1958a) stated that they are the most complex of the darters. *E. maculatum* appears to have similar breeding habits except the eggs are laid in a wedge-shaped mass rather than in a single layer (Raney and Lachner 1939).

Winn (1958b) reported that in darters he examined there was an inverse correlation between extent of care and the numbers of eggs laid. The fewest number of eggs laid were by *E. nigrum*, *E. maculatum*, and *E. flabellare* which exhibit the greatest parental care. Williams (1959) has also shown that ovarian weights in *E. flabellare* and *E. nigrum* that exhibit parental care are higher than in *E. caeruleum* and *E. spectabile* where there is no parental care.

TABLE 4.—SEX RATIOS FOR 1,211 FANTAIL DARTERS FROM BRASHEARS CREEK, 1972 AND 1973. RATIOS ARE PERCENTAGES

Month	Males	Females	Sex Ratio
Jun	129	85	60.40
Jul	148	66	69:31
Aug	22	22	50:50
Sep	45	17	72:28
Oct	91	37	71:29
Nov	25	15	62:38
Dec	69	58	54:46
Jan	70	44	61:39
Feb	69	36	66:34
May	57	39	59:41
Total	725	486	64:36

Sex Ratio

In Brashears Creek, males dominated females at a ratio of 64:36 (Table 4). Sex ratios were based on all fish collected except those in Age Group 0 in June through October whose sex could not be determined because the gonads were not sufficiently developed. The dominance of males was due to a differential mortality rate rather than to a differential birth rate. The sex ratio for fish in Age Group 0 in December was almost equal, 51:49. Males became increasingly more dominant with age, sex ratios of Age Groups 1 and 2 being 63:37 and 86:14, respectively, in June. Only 2 females in Age Group 2 were collected from Brashears Creek throughout the entire study. The differential mortality observed in Brashears Creek resulting in sex ratios favoring males may be due to reproductive behavior and predation. Females during the spawning period are more susceptible to environmental factors as well as predation because of the female's wandering nature at that time, going from nest to nest. Males maintain the nest and, therefore, are not as exposed as the females.

The sex ratio of the combined collections

from the other stations in the Salt River system was 61 males to 49 females. Although the combined collections did favor males, sex ratios at 4 stations favored females. Sex ratios, for *E. flabellare* reported by Lake (1936) and Schwartz (1965) have shown that females outnumbered males about 2 to 1. Sex ratios for *E. flabellare* appear extremely different in different localities, as Raney and Lachner (1943) have reported for *Boleosoma nigrum olmstedi*. Sex ratios of other darters generally show a tendency for males to exceed females (Raney and Lachner 1939, Lachner et al. 1950).

SUMMARY

The fantail darter was abundant throughout the Salt River drainage. The life span was 2.5 years for males and 2 years for females. Growth was greatest in the first month, tripling its initial length. Coefficient of condition was highest in July when water temperatures were optimum and lowest in November when water temperatures were low. Females had a higher coefficient of condition in winter and a lower condition in the spring due to the additional weight of the ovaries. Food of the fantail darter was aquatic insects consisting of Diptera (primarily chironomids), Ephemeroptera, Trichoptera, Plecoptera, and other benthic organisms in order of importance. Food habits changed seasonally as the benthic fauna changed. Different size groups exhibited no difference in food habits. In Brashears Creek, there was always an adequate food supply, even in the summer when the numbers of aquatic insects were at their lowest. The peak spawning period was in April and extended into May. Young of the year appeared in the riffles in June. Males outnumbered females at a ratio of 61:39 in the Salt River and 64:36 in Brashears Creek. The dominance of males was due to differential mortality rate rather than to a differential birth rate.

LITERATURE CITED

BAILEY, R. M., J. E. FITCH, E. S. HERALD, E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, AND W. B. SCOTT. 1970. A list of common and scientific names of fishes from the United States and Canada (Third Edition). Amer. Fish. Soc. Spec. Publ. No. 6. Washington, D.C. 150 pp.

BURKS, B. D. 1953. The Mayflies or Ephemeroptera of Illinois. Bull. Ill. Nat. Hist. Surv. 26(1):1–216.

HENDRICKSON, G. E., AND R. A. KRIEGER. 1964. Geological survey water supply paper 1700. U.S. Govt. Print. Off., Washington, D.C., 135 pp.

HOYT, R. D., W. E. NEFF, AND L. A. KRUMHOLZ. 1970. An annotated list of fishes from the upper Salt River, Kentucky. Trans. Ky. Acad. Sci. 31(3–4):51–63.

KARR, J. R. 1964. Age, growth, fecundity and food habits of fantail darters in Boone County, Iowa. Iowa Acad. Sci. 71:274–280.

LACHNER, E. A., E. F. WESTLAKE, AND P. S. HANDWERK. 1950. Studies on the biology of some percid fishes from western Pennsylvania. Amer. Midl. Nat. 43(1):92–111.

LAGLER, K. R. 1969. Freshwater Fishery Biology. W. C. Brown Co., Dubuque, Iowa. 421 pp.

LAKE, C. T. 1936. The life history of the fantailed darter, *Catonotus flabellaris flabellaris* (Rafinesque). Amer. Midl. Nat. 7(5):816–830.

LARIMORE, R. W. 1957. Ecological life history of the warmouth (Centrarchidae). Bull. Ill. Nat. Hist. Surv. 27(1):1–83.

NEFF, S. E., AND L. A. KRUMHOLZ. 1974. A detailed investigation of the sociological, economic, and ecological aspects of proposed reservoir sites in the Salt River Basin of Kentucky. Univ. Ky. Water Res. Inst., Res. Rept. No. 67. 64 pp.

PENNAK, R. W. 1953. Fresh-water Invertebrates of the United States. The Ronald Press, New York, N.Y., 769 pp.

PFLIEGER, W. L. 1975. The fishes of Missouri. Mo. Dept. Cons., Columbia, Mo. 343 pp.

RANEY, E. C., AND E. A. LACHNER. 1939. Observations on the life history of the spotted darter, *Poecilichthys maculatus* (Kirtland). Copeia 1939(3):157–165.

————, AND ————. 1943. Age and growth of johnny darters, *Boleosoma nigrum olmstedi* (Storer) and *Boleosoma longimanum* (Jordan). Amer. Midl. Nat. 29(1):229–238.

ROSS, H. H. 1944. The Trichoptera or caddisflies of Illinois. Bull. Ill. Nat. Hist. Surv. 23: 1–326.

SCHWARTZ, F. J. 1965. Densities and ecology of the darters of the upper Allegheny River watershed, Pp. 95–103. *In* C. A. Tryon, Jr., R. T. Hartman, and K. W. Cummins (Eds.). Studies on Aquatic Ecology of the Upper Ohio River System. Pymatuning Laboratory of Ecology Spec. Publ. No. 3, Univ. Pittsburgh, Pittsburgh, Pa. 103 pp.

TSAI, C. 1972. Life history of the eastern johnny darter, *Etheostoma olmstedi* Storer, in cold tailwater and sewage-polluted water. Trans. Amer. Fish. Soc. 101(1):80–88.

USINGER, R. L. 1956. Aquatic Insects of California. Univ. Calif. Press, Berkeley, Los Angeles, Cal. 508 pp.

WILLIAMS, G. C. 1959. Ovary weights of darters: a test of the alleged association of parental care with reduced feundity in fishes. Copeia 1959(1):18–24.

WINN, H. E. 1958a. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecol. Monogr. 28(2):155–191.

————. 1958b. Observations on the reproductive habits of darters (Pisces–Percidae). Amer. Midl. Nat. 51(1):190–212.

Trans. Ky. Acad. Sci., 39(3–4), 1978, 160–163

The Elimination of Fluctuations During the Use of a Nitrate Specific Ion Electrode

Linda L. Blaine and Frank R. Toman
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Fluctuations in millivolt readings were found to occur when using an Orion nitrate specific ion electrode to measure nitrate concentration.

Those fluctuations were greatest in the weaker nitrate solutions (10^{-4} M and 5×10^{-4} M) and were more pronounced when the electrode had not been renewed for a while. The fluctuations could be reduced greatly if the electrode was preequilibrated in sodium nitrate solution for 0.5 hour with stirring before taking the readings.

Introduction

During experiments in which a nitrate specific ion electrode was used to measure nitrate concentrations, it was observed that millivolt readings for standard sodium nitrate solutions sometimes varied considerably. It was not known if that type of fluctuation varied with the length of time since electrode renewal or if it was a characteristic of all nitrate electrodes. Millivolt readings have an inverse relationship with nitrate concentration. The present study was undertaken to evaluate the precision of the nitrate electrode and to determine the conditions of use under which reproducible results could be obtained.

Materials and Methods

The nitrate specific ion electrode, Orion Model 92-07, was the subject of this study. The reference electrode was a single junction reference electrode, Orion Model 90-01. The electrodes were used in a Corning Model 12 research pH meter.

Dioxane, sodium nitrate, and potassium chloride were of reagent grade. Liquid ion exchanger, 92-07-02, and internal filling solution, 92-07-03, were from Orion Research. Phenyl mercuric acetate was obtained from Eastman Kodak.

Sodium nitrate was used to prepare a 1.0 M solution. The reference electrode was kept filled with 0.1 M potassium chloride. Preservative was prepared by dissolving 0.1 g of phenyl mercuric acetate in 20 ml of dioxane, then diluting to 100 ml with distilled deionized water.

Standards were prepared daily by making dilutions of the 1.0 M sodium nitrate stock solution with glass distilled deionized water. Experiments were run utilizing the following 5 sodium nitrate standards: 10^{-4} M, 5×10^{-4} M, 10^{-3} M, 5×10^{-3} M, and 10^{-2} M. One ml of preservative was added to each liter of distilled deionized water used to prepare standards.

Nitrate electrodes were renewed according to instructions in the Orion Nitrate Ion Electrode Manual (1970).

Four separate experiments were designed to evaluate the electrodes under study and to attempt to obtain reproducible results: (1) no pretreatment of the nitrate electrode, (2) electrodes were rinsed and dried, then immersed in dilute nitrate solution, the switch turned on, and preequilibrated for 0.5 or 1 hour, (3) electrodes renewed on the day prior to use, then preequilibrated for 0.5 hour without stirring and preequilibrated 0.5 hour with stirring, and (4) sensitivities of 3 different nitrate specific ion electrodes were compared; each had been renewed prior to the experiment.

Results and Discussion

Experiment 1—No Pretreatment of Nitrate Electrode

The 5 sodium nitrate standards were read on 5 different days from weakest to

strongest and repeated until reproducible results were obtained (Table 1, Column 1). This required from 45 min to 1 hour each day. The values in the table are the differences in readings for a particular standard between the first and last reading and are the averages for 5 trials on 5 different days. Actual readings ranged from 163 millivolts (mv) to 40 mv on the 10^{-2} M standard. On each day, readings decreased as the standards were read repeatedly. The lower readings indicated that the electrode possessed greater sensitivity after being used for a period of time.

From the results of this experiment, it was decided to test electrodes after they had been preequilibrated for 0.5- and 1-hour periods.

Experiment 2—Pretreatment of the Nitrate Electrode: 0.5 Hour vs. 1 Hour Preequilibration

After the electrodes were rinsed and dried and preequilibrated for 0.5 hour or 1 hour, the nitrate standards were read in the same manner as described for Experiment 1 (Table 1, Columns 2, 3). The values in each column are averages for 4 trials on 4 different days.

Preequilibration for 0.5 hour reduced the amount of total change from the first to the last reading when compared to readings with no treatment. Preequilibration for 1 hour was of very little or no greater benefit than preequilibration for 0.5 hour.

Experiment 3—Pretreatment of a Recently Renewed Electrode: 0.5 Hour Preequilibration vs. 0.5 Hour Preequilibration with Stirring

On the day prior to the beginning of this experiment, the electrode was renewed to determine the stability of readings during the first hour of use following renewal. Nitrate standards were read on 9 different days. On 3 days, the electrode received no pretreatment, and on 3 days, the electrode received 30 min preequilibration as described in Experiment 2. On the other 3 days, the electrode received the same type of pretreatment with the dilute nitrate solution kept in motion with a magnetic stirrer (Table 2). Values for each column are averages for 3 trials.

TABLE 1.—DIFFERENCES IN MILLIVOLTS BETWEEN THE FIRST AND THE LAST READING OF STANDARD SOLUTIONS

Conc.	No preequilibration	0.5 hour preequilibration	1 hour preequilibration
1×10^{-4} M	4.5	2.9	3.1
5×10^{-4} M	2.7	2.0	1.5
1×10^{-3} M	2.1	1.6	1.1
5×10^{-3} M	2.5	1.6	1.5
1×10^{-2} M	2.3	1.4	1.1

This experiment generally showed less change in readings under conditions of no pretreatment when the nitrate electrode had been recently renewed than it did in earlier experiments when it had not been recently renewed (Table 2, Column 1; Table 1, Column 1). The same general trend is indicated when changes in readings after the electrode had been equilibrated for 0.5 hour are compared for recently renewed and not recently renewed electrodes (Table 2, Column 2; Table 1, Column 2). There still remained, however, less change in readings after a 0.5-hour preequilibration period than with no pretreatment in the renewed electrode (Table 2, Columns 1, 2). This further substantiates the need for preequilibration before using the nitrate electrode. The preequilibration apparently is even more important as the electrode ages.

The data reported in Table 2, Column 3, when the electrode was preequilibrated in a dilute nitrate solution kept in motion with a magnetic stirrer, showed less change than with no pretreatment or with 0.5 hour pretreatment with no stirring (Table 2). This indicated that not only is preequilibration important, but that stirring increased the effectiveness of the equilibration period. It should be noted that most of the change in readings during the first week of use after renewal was in the weaker solutions, 10^{-4} M and 5×10^{-4} M (Table 2).

TABLE 2.—DIFFERENCES IN MILLIVOLTS BETWEEN THE FIRST AND THE LAST READING OF STANDARD SOLUTIONS DETERMINED ON A RECENTLY RENEWED ELECTRODE

Conc.	No pre-treatment	0.5-hour pretreatment	0.5-hour pretreatment with stirring
1×10^{-4} M	4.3	2.0	1.1
5×10^{-4} M	1.5	0.3	0.5
1×10^{-3} M	0.7	0.8	0.3
5×10^{-3} M	0.7	1.0	0.3
1×10^{-2} M	0.7	0.5	0.3

Experiment 4—Comparison of 3 Different Nitrate Ion Electrodes

The original Orion nitrate specific ion electrode and 2 other electrodes borrowed from other university departments were renewed before the experiment was begun. Readings were recorded on 6 different days for each electrode, on 3 days, 30-min pre-equilibration with the magnetic stirrer, and 3 days with no pretreatment. The electrodes from the Departments of Agriculture, Biology, and Chemistry, are referred to as Electrodes A, B, and C, respectively (Tables 3, 4). Values are averages for 3 trials on 3 different days.

Previous results with Electrode B showed changes in values during the first half hour of use, and continued in this experiment (Tables 3, 4). The same trend was demonstrated by the other 2 electrodes. Apparently, fluctuations during the first half hour of use are characteristic of all Orion nitrate specific ion electrodes.

TABLE 3.—DIFFERENCES IN MILLIVOLTS BETWEEN THE FIRST AND THE LAST READING OF STANDARD SOLUTIONS DETERMINED ON 3 DIFFERENT ELECTRODES UTILIZING A 0.5-HOUR PREEQULILBRATION PERIOD WITH STIRRING

Conc.	Electrode A	Electrode B	Electrode C
1×10^{-4} M	2.8	4.1	1.5
5×10^{-4} M	0.5	2.1	0.7
1×10^{-3} M	0.8	1.0	0.7
5×10^{-3} M	0.7	0.3	0.5
1×10^{-2} M	0.3	0.5	0.7

TABLE 4.—DIFFERENCES IN MILLIVOLTS BETWEEN THE FIRST AND THE LAST READING OF STANDARD SOLUTIONS DETERMINED ON 3 DIFFERENT ELECTRODES WITH NO PRETREAMENT

Conc.	Electrode A	Electrode B	Electrode C
1×10^{-4} M	3.1	5.8	1.8
5×10^{-4} M	1.3	3.8	1.8
1×10^{-3} M	0.7	2.7	1.7
5×10^{-3} M	0.5	2.0	1.3
1×10^{-2} M	0.5	1.3	1.1

Experiment 4 also showed that changes in behavior of a nitrate ion electrode can be expected between 2 and 4 weeks after being renewed, and is in agreement with an evaluation of the nitrate electrode by Potterton and Schuts (1967). The experiment showed, however, that when working with dilute nitrate solutions, a freshly renewed electrode does not assure that reproducible results will be achieved. In all cases, changes greater than 1.0 mv were obtained with a freshly renewed electrode with no pretreatment when working with solutions of 10^{-4} M concentration (Table 4). Pretreatment with a stirred solution of sodium nitrate reduced changes, but some change in readings was still observed. Thus, the nitrate electrode, when freshly renewed and pretreated as described above, did not give reproducible results for solutions of 10^{-4} M concentration. In all cases, however, reproducible results were obtained eventually for the dilute solutions after the electrode had been in use for about 0.5 hour.

A recently renewed nitrate electrode, when used with more concentrated solutions (10^{-3} M to 10^{-2} M), did not show the variation that exists with dilute solutions (Tables 3, 4). Variations occurred for the more concentrated solutions when the electrode had aged. For Electrode B, greater variation occurred about a month after renewal, and the variation was much more pronounced when the electrode had not been pretreated. There were no millivolt variations after the electrode had been in use for approximately 0.5 hour.

Millivolt readings for nitrate solutions of

10^{-4} M and 5×10^{-4} M with Electrode B, pretreated or not, showed a greater percentage variation than with more concentrated solutions. Even for the lower concentrations, since readings did eventually become reproducible, there was no indication that the electrode failed to give dependable readings when proper technique was utilized as long as 4 to 6 weeks after renewal.

CONCLUSIONS

Experimental results with an Orion nitrate specific ion electrode indicated that millivolt readings decreased during the first half hour of use. Pretreatment by soaking the electrode in dilute nitrate solutions for 0.5 hour reduced but did not eliminate the variation in readings. Preequilibration for 1 hour was of little more benefit than a half hour, but stirring the solution during pretreatment increased the effectiveness.

There was less variation in readings during the first half hour of use when the nitrate electrode had been renewed recently. Variation was further decreased by use of a half-hour preequilibration with stirring. Change in readings was minimal in the stronger nitrate solutions (10^{-2} M to 10^{-3} M), particularly if the fresh electrode was preequilibrated. Weaker nitrate solutions consistently showed greater variations than stronger solutions. For all concentrations, greater variation occurred in readings as the electrode aged. In all cases, readings became reproducible after the electrode had been in use for approximately 0.5 hour.

Comparison of 3 different electrodes indicated that all Orion nitrate specific ion electrodes give similar results when tested under similar conditions. Regardless of factors such as length of time since renewal or nitrate solution concentration, maximum reliability in the electrode is obtained by reading aliquots of a dilute nitrate solution for at least 0.5 hour and determining that stability had been reached prior to making the determinations.

LITERATURE CITED

ORION RESEARCH INC. 1970. Instruction manual, nitrate ion electrode, Model 92-07. Orion Research Inc., Cambridge, Mass. 5 pp.

POTTERTON, S. S., AND W. D. SCHUTS. 1967. An evaluation of the performance of the nitrate-selective electrode. Anal. Lett. 1:11.

NEWS AND COMMENT

Annual Meeting The Sixty-fourth Annual Meeting of the Kentucky Academy of Science will be held at Eastern Kentucky University, Richmond, on 3 and 4 November 1978. Registration will commence at noon on 3 November in the main lobby of Moore Building. The Annual Banquet will be held in Keen Johnson Banquet Hall at 1830 on 3 November, and Dr. David Pimentel, Cornell University, Ithaca, New York, will speak on "Energy in Food Production." The Annual Business Meeting will begin at 0800 on 4 November. Hosts for the meeting are Ted George and Sanford Jones. Be sure to make your room and banquet reservations promptly.

* * * * *

Membership Drive The Executive Committee of the Academy has requested that the membership drive begun so ably by Don Batch will be extended to this year's Annual Meeting. Any active member who nominates five or more persons for membership will receive a free ticket to the Annual Banquet. The new membership forms are available from Don Batch (Eastern), Tom Seay (Georgetown), and Lou Krumholz (Louisville), and they will be pleased to supply you with as many such forms as you wish. Our goal is 1,000 plus members.

* * * * *

Distinguished Scientist Award If you haven't done so already, please be sure to send your nominations for the Academy's Distinguished Scientist for 1978 to Dr. Harold W. Eversmeyer, Department of Biological Sciences, Murray State University, Murray, Kentucky 42071. Be sure to include adequate information on your candidate's achievements along with a reasonably complete vita.

Institutional Affiliation Ten institutions of higher education in Kentucky have become Institutional Affiliates of the Kentucky Academy of Science during 1978. They are listed in alphabetical order. We sincerely hope they continue such affiliation for years to come.

Alice Lloyd College
Bellarmine College
Eastern Kentucky University
Kentucky State University
Kentucky Wesleyan
Morehead State University
Murray State University
Northern Kentucky University
University of Louisville
Western Kentucky University

The Kentucky Academy of Science extends its deep appreciation for that support.

* * * * *

NSF Chautauqua-Type Short Courses Fourteen short courses in the 1978–1979 series of NSF Chautauqua-Type Short Courses for college teachers will be open to a limited number of scientists and engineers in industry. The courses will be held at two of the regional field centers, The Oregon Graduate Center for Study and Research and the University of Hartford. For further information, contact the Department of Materials Science, 19600 N.W. Walker Road, Beaverton, Oregon 97005, or the Chautauqua Field Center, 451 Dana Hall, West Hartford, Connecticut 06117.

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Index The index and contents of volume 39 will be distributed as a separate insert with the March 1978 issue of volume 40 of the *Transactions*.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and, once accepted, an attempt will be made to publish papers in the order of their acceptance. Manuscripts should be typed, double spaced throughout, on good quality white paper 8½ × 11 inches (216 × 279 mm). The original and one copy should be sent to the Editor and the author should retain a copy for his own use in correcting proof. Metric and Celsius units are to be used for all measurements instead of, or in addition to, English and Fahrenheit units. Format and style may vary somewhat depending on the scientific discipline, but the basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of papers in the Journals of the American Chemical Society, the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and A Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined.

The sequence of material in the manuscript should be: title page, abstract, body of the manuscript, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the author's name and address, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the body of the paper.

3. The body of the manuscript should include the following sections: Introduction, Acknowledgments (if applicable), Materials and Methods, Results, Discussion, Summary, and Literature Cited. In manuscripts of only a few pages, there is no need to break it up into sections, except for the Literature Cited. All tables and figures, as well as all literature cited must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to, as in the following examples:

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Johnson, A. E., and E. V. Harrell. 1962. An analysis of factors governing density patterns in desert plants. J. Bot. 44(3):419–432.

Book:

Darlington, P. J., Jr. 1965. Biogeography of the southern end of the world. Harvard Univ. Press, Cambridge, Mass. 236 pp.

5. Each table, together with its heading, must be double spaced, numbered in arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5 × 7 or 8 × 10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than 8½ × 11 inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and such costs are to be borne by the author. Reprints are to be ordered when the galley proofs are returned to the Editor.

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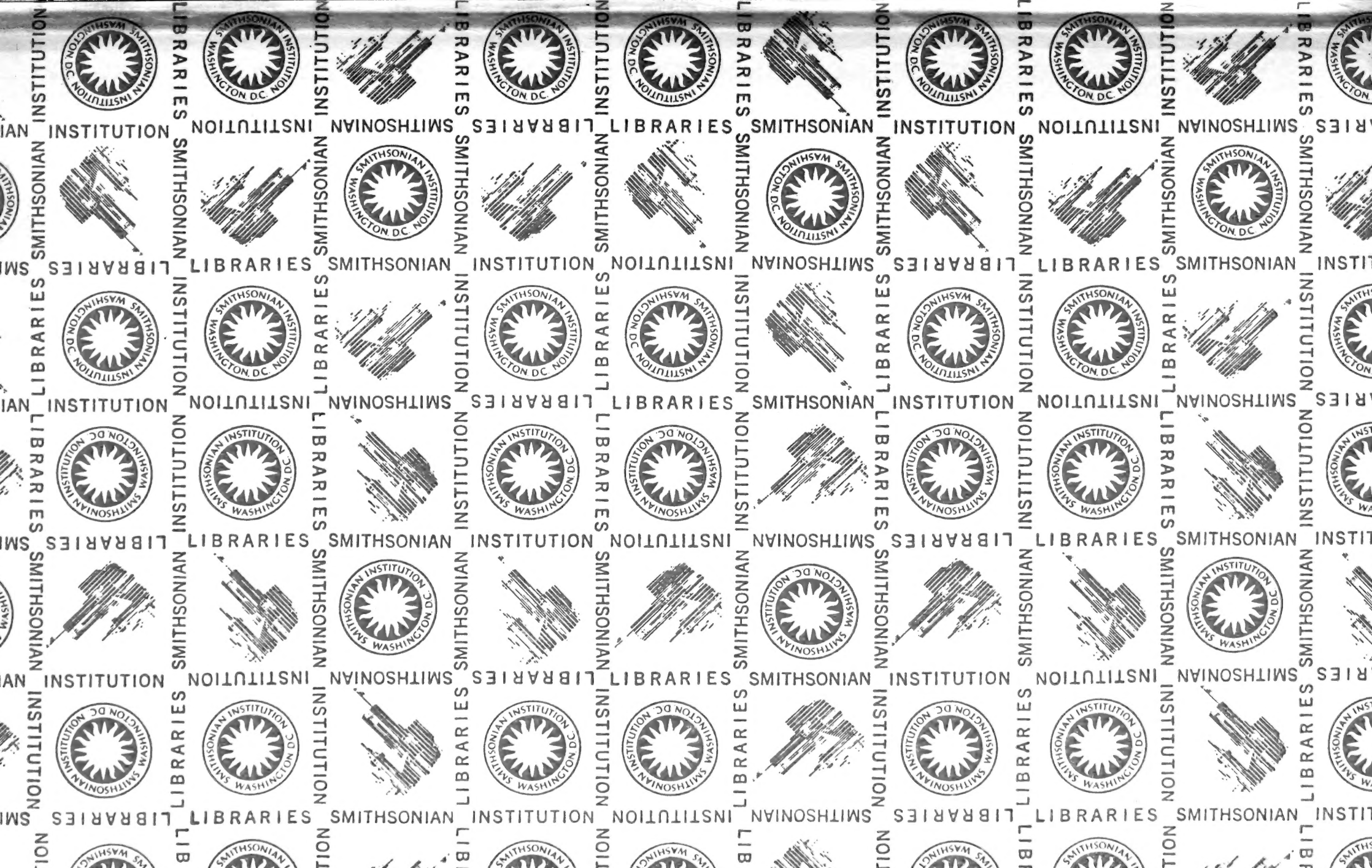
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